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PART II
VOLUME I
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THE PHYSIOLOGICAL BASIS FOR VARIOUS CONSTITUENTS IN SURVIVAL RATIONS

Part II. The Efficiency of Young Men Under Conditions of Moderate Cold

FREDERICK SARGENT, II, CAPTAIN, USAF (MC)
VIRGINIA W. SARGENT, M.S.
ROBERT E. JOHNSON, M.D., D. PHIL. (OXON.)
STANLEY G. STOLPE, PH.D.

UNIVERSITY OF ILLINOIS

MAY 1955

WRIGHT AIR DEVELOPMENT CENTER

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AERO MEDICAL LABORATORY
CONTRACT No. AF 18(600)-80
PROJECT No. 7156

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

The investigations described in this report were carried out in three principal phases. A detailed protocol for a winter field test was designed in November and December of 1953. A 42-day metabolic investigation was made under field conditions at Chanute AFB, Illinois, and Camp McCoy, Wisconsin, in the months of February, March, and April 1954. The biological specimens collected and the clinical observations made were analyzed in the laboratories of the Health Service Research Unit, McKinley University Hospital, and the Department of Physiology, University of Illinois, Urbana, between April and December 1954. The research was supported by Contract No. AF 18(600)-80, with Aero Medical Laboratory, Directorate of Research, WADC, Project No. 7156, "Flight and Survival Foods, Feeding Methods, and Nutritional Requirements," Task No. 71805, "Nutritional Physiology of Men Under Air Force Operating Conditions and Emergency Situations," (formerly RDO No. 698-81, "Survival Ration Requirements"). The Contract Monitor was Dr. H. C. Dyme, Chief, Nutrition Section, the Project Scientist, Lt. Col. A. A. Taylor, USAF (MC), and the Task Engineer, Dr. R. F. Kline, also of the Nutrition Section, Aero Medical Laboratory, WADC. Lt. Col. Roy W. Otto, Chanute AFB, served throughout as the Project Officer. This report constitutes the results of the joint efforts of the responsible investigators, R. E. Johnson, F. Sargent, II, and S. G. Stolpe, and a team of civilian and military associates to whom most of the credit should go for the success of these studies. A team roster is included in Section VII: Acknowledgements.

This investigation would not have been possible without the generous cooperation of the University Health Service, especially in making space available in laboratories of the Health Service Research Unit at McKinley University Hospital, University of Illinois.

We wish to acknowledge the generous cooperation received from Air Research and Development Command, Air Training Command, Fifth Army, and the Purchasing Department of the University of Illinois. To Mrs. Norma Templin we extend our thanks for assistance in editing this report. To Mr. Jamal Samiany we are indebted for the quantitative charts.

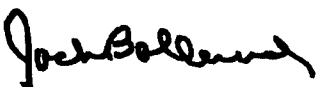
ABSTRACT

From February 22, 1954, through April 4, 1954, 87 volunteer airmen and 12 volunteer non-commissioned officers served as subjects in a study of survival rations in moderate cold at Chanute AFB and in the field at Camp McCoy, Wisconsin. The base laboratory was at McKinley Hospital, University of Illinois, Urbana. To establish physiological, biochemical, nutritional, and clinical judgments on the relative effects of work, water, calories, and protein/carbohydrate/fat ratio in all-purpose survival rations, numerous observations were made in two-week periods of adequate, restricted, and recovery diets, with luxus amounts of vitamins at all times. Starvation and a 3000-Calorie adequate ration represented the worst and best regimens. Twenty nutrient combinations could be rank-ordered, by 21 different tests, with respect to effects on organ function and body efficiency. Clinical findings could also be rated. Below the 3000-Calorie control ration, the highest score was attained both in hard work and in light work by a combination supplying unlimited water, 2000 Calories per day, and a distribution of calories of 15% protein, 52% carbohydrate, and 33% fat. Limitation of water, decrease of calories, or marked deviations in protein/carbohydrate/fat ratios resulted in measurable clinical or functional deterioration.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:



JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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SECTION I

GENERAL INTRODUCTION

In a previous report (Sargent, Sargent, Johnson, and Stolpe, 1954) the problem of the all-purpose all-environment survival ration was discussed on the basis of a comprehensive study of young men subsisting on a variety of nutrient combinations under temperate conditions and with only moderate physical activity. The present study extends this work to include two additional major variables - hard physical exertion and exposure to cold weather in the field. An important aspect of this work was to make judgements on the relative merits of a variety of nutrient combinations in sustaining maximally the "survival potential" (Kline and Dyme, 1953) of castaways forced to survive, escape, and evade in cold weather.

The general planning of the cold weather test called for a mass metabolic study on 87 volunteer airmen observed continuously for a six-week period at Chanute Air Force Base, Illinois, and Camp McCoy, Wisconsin. The organ function and bodily efficiency of the subjects were studied during two preliminary weeks, two experimental weeks, and two recovery weeks by the same comprehensive battery of tests that had been employed in the temperate study. Furthermore, during the two experimental weeks of the two studies comparable regimens of total calorie intake, water intake, ratio of protein, carbohydrate, and fat, and inorganic nutrients were administered. Thus, it became possible to determine the impact of hard physical work and cold weather on nutritional stresses to which the castaway might be exposed.

This cold weather study was planned to avoid the major criticisms which can be leveled at most previous studies on this question. A truly comprehensive study was made of the multiple nutritional interrelations which must be considered in any survival ration; viz., degree of water deficit, amount of caloric deficit, and varying ratios of protein, carbohydrate, and fat in the survival ration. Statistical validity was insured by adequate numbers of paired controls; and adequate range of water deficit, calorie deficit, and nutrient combinations. Finally the impact of cold weather and exercise was studied realistically in field survival situations.

The present study had two major aims. The first was to extend previous knowledge of survival rations by a systematic survey of the effects on human subjects of the possible combinations of water intake, calorie intake, and protein/carbohydrate/fat ratios in potential survival rations. Emphasis has been principally on efficiency of the body as a whole and the functioning of important organ systems. In other words, our emphasis has been on the health and welfare of the castaway himself, in addition to orthodox biochemical and nutritional interpretations of intakes, balances, and composition of blood and excreta. Second, the data were to be obtained under realistic field conditions in which volunteer airmen were exposed to cold weather and hard work. The impact of these two stresses could be interpreted in the light of control data obtained in 1953 in which normal young men were exposed to the

same nutritional stresses but under conditions of temperate environment and moderate exercise. As in 1953 it was planned in 1954 to gather as much information as possible on rehabilitation of the rescued castaway and on the nutritional merits of the 5-in-1 ration.

Because a unique opportunity was arranged by the Air Force so that large numbers of subjects, excellent field facilities, and supporting personnel became available, it became possible to organize the present study for statistically valid conclusions from a wide variety of dietary, biochemical, physiological, and clinical observations. The concepts of controls were paramount in the ultimate design. Each subject was his own control in that he was subsisted for two weeks on an adequate ration under conditions of moderate environmental exposure and exercise, then for two weeks on an experimental nutrient combination under field survival conditions, and finally for two weeks on rehabilitation regimens under conditions of moderate environmental exposure and exercise.

A second control concept was that of paired control in the field phase not only for nutrient intake but also for water intake and work output. For this purpose the volunteer subjects were divided into four major groups:

Flight 1 Hard work, unlimited water
Flight 2 Hard work, limited water
Flight 3 Light work, unlimited water
Flight 4 Light work, limited water

The hard work group simulated castaways attempting to escape and evade with or without restricted water and the light work groups simulated castaways surviving in one spot with or without limitation of water. Within each flight two subjects subsisted on each of the ten nutrient combinations under study. Thus, within each flight there were paired controls for each nutrient combination.

Two additional control concepts were utilized in the study of nutrient combinations; i.e., the concept of negative and positive control and the concept of ration control. Negative control consisted of starvation, in which presumably survival potential is least maintained. Positive control consisted of a 3000-Calorie diet very similar in composition (but lower in calories) to field rations used by Peary (1910) and Amundsen (1908, 1913) in their polar journeys. This ration was considered to maintain survival potential better than 2000- or 1000-Calorie regimens. The ration controls were flight leaders who lived and worked with their men without any restriction of fluid intake or calorie intake, their food being provided at all times from a garrison ration in a mess hall. To the best of our knowledge no other major field study has incorporated this kind of control in which presumably physiological and biochemical changes are conditioned solely by work and weather, not by nutritional stresses.

No attempt was made to study and compare survival rations already in production. Rather the study was designed to establish conclusively underlying physiological and clinical principles upon which the technologists can build the best and most acceptable ration for survivors.

SECTION II

METHODS

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A. ADMINISTRATIVE ASPECTS OF FIELD TRIAL

1. Background, Planning, and Organization

The preliminary discussions for a series of investigations on the physiological basis of constituents of the survival ration began in January, 1951. At that time it was conceived that an investigation in three phases would yield the most information: (1) a control study in which the subjects engaged in moderate activity and received a minimum exposure to environmental stress, (2) a field trial in which the subjects would be exposed to cold weather, and (3) a field trial in which the subjects would be exposed to hot weather. In the latter two studies some subjects would be doing hard work, others light work. The control study has been completed and a report has been submitted (Sargent et al., 1954). In the present report this study will be referred to as the 1953 or temperate study. The present investigation will be referred to as the 1954 or cold weather study.

The Air Training Command (ATRC) and the Air Research and Development Command (ARDC) agreed to collaborate with the Department of Physiology, University of Illinois, in furnishing (1) the sites for the trials, (2) the required support personnel, (3) the supplies and equipment, (4) the volunteer subjects, and (5) the transportation facilities. The assistance of the 3345th Training Wing (ATRC) at Chanute Air Force Base, Rantoul, Illinois, was enlisted and Chanute AFB and Camp McCoy, Wisconsin, were designated as the sites for the test.

The key administrative personnel were appointed in December 1953 ---- project officer, supervisory investigator, and supply sergeant ---- and work was initiated on the detailed planning and organization. The organization utilized is shown in Figure 1. This arrangement proved to be workable and through it there developed a splendid team spirit to which the success of the undertaking was directly attributable. The project officer accomplished the following: (1) appointment of administrative personnel (adjutant, first sergeant, supply sergeant, transportation sergeant, flight non-commissioned officers, and medical non-commissioned officers), (2) procurement of living facilities for subjects, laboratory facilities, administrative and supply buildings, and a mess hall where the subjects could be fed at Chanute AFB, (3) procurement of necessary supplies and equipment for these facilities, (4) procurement of transportation vehicles to be used at Chanute AFB and Camp McCoy, (5) arrangement to have a B-25 make a daily flight between Chanute AFB and Camp McCoy to transport fresh food and biological specimens, and (6) arrangements for administrative, supply, laboratory, messing, and living facilities at Camp McCoy and the encampments for the subjects.

The supervisory investigator was responsible for (1) the planning of the scientific aspects of the trial, such as testing, work loads to be imposed, and nutrient combinations to be fed, (2) ordering necessary supplies and equipment for testing and feeding the subjects and for collecting various biological specimens, (3) preparing forms and other devices for recording the scientific observations, (4) obtaining containers for the transportation of laboratory equipment and supplies and biological specimens, and (5) pro-

curing a facility for cold storage of biological specimens.

The cold-weather clothing for the subjects and support personnel, the tentage, and other accessory equipment and supplies for the field phase of the trials was arranged for by the Aero Medical Laboratory which also furnished all rations and ration components used by the test subjects. Medical supplies medicaments, and devices for physical examination were provided by the 3345th Medical Group at Chanute AFB. ATRC and ADRC jointly supplied the necessary medical officers and the University field staff of technical personnel was supplemented by scientists from the Aero Medical Laboratory. Arrangements were made to obtain the required 88 volunteer subjects from ATRC at Lackland AFB, Texas.

2. Administration of Support Personnel

There were some 40 individuals who directly supported the daily conduct of the trial. In order that these individuals could be familiarized with the purposes of the investigation and briefed on daily plans so that they could carry out their individual duties, two procedures were followed. (1) In the week prior to beginning the trial all responsible individuals were given detailed briefings on the general purpose of the trial, the nature of clinical investigation, and the many problems that might be faced during the course of the trial. These briefing sessions were held with specific groups (e.g., clinical laboratory personnel, flight non-commissioned officers, mess group, etc.) so that the special aspects of their mission could be emphasized. (2) After the trial had actually begun, daily conferences were held with these groups or representatives from the groups so that the next day's program could be explained, orders could be issued, and special problems given prompt attention.

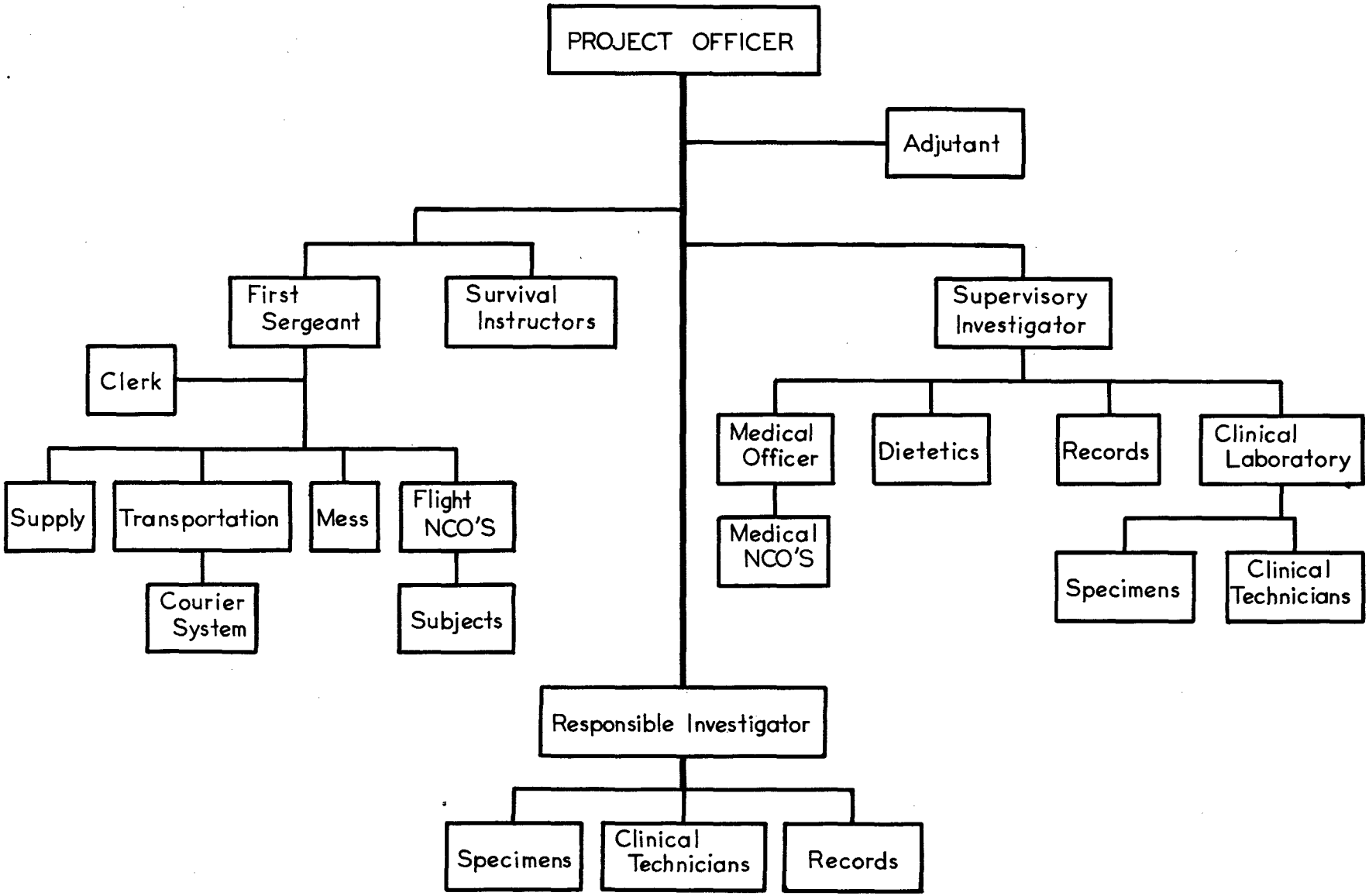
3. Administration of the Subjects

Two groups of persons had direct administrative control of the subjects: (1) non-commissioned officers in charge of flights and (2) survival instructors.

Non-Commissioned Officers of Flights. There were four major groups of subjects designated as Flights 1, 2, 3, and 4. Each flight was planned to contain 22 men. Three NCO's were in charge of each. These men were hand-picked by the project officer for their reliability, stability, and leadership. The ranking NCO in each case was the flight leader. These 12 men were charged with the primary responsibility of maintaining control of the subjects which involved implementing the instructions given the subjects. (These instructions are detailed in a subsequent section.) In addition they maintained a daily diary on each subject and participated in the conduct of instruction and certain tests on the subjects. They also agreed to serve as subjects in a number of the scientific procedures. They had no mean task, and it was due in large part to their enthusiastic support of the trial that the scientific data collected are entirely trustworthy.

FIGURE II. 1. ORGANIZATIONAL CHART FOR THE WINTER TRIALS CONDUCTED FEBRUARY TO APRIL 1954.

FIG. II. 1
ORGANIZATIONAL CHART: WINTER 1954



These 12 men were given especially intensive briefing before the trial began. During the trial it was through them that orders, schedules, and other details were passed on to the subjects.

Survival Instructors. One survival instructor was attached to each flight. These men had two primary duties: (1) to assist in the administrative control of the subjects and (2) to give survival lectures and demonstrations and to lead the subjects in field survival practice. (The details of the program of survival instruction will be given in a subsequent section.) These men together with the flight non-commissioned officers played a vital role in providing entertainment and recreation for the subjects who, of necessity, had to be maintained under rather confining circumstances.

4. The Movement to and from Camp McCoy

One of the most difficult aspects of the trial was the movement of the subjects and test team to and from Camp McCoy. The metabolic regimen (described below) was maintained during both trips. The movement to Camp McCoy was made by train, all personnel riding in coaches. An advance cadre had prepared the headquarters area (mess hall, laboratory, sleeping quarters, supply, and administration) and the campsites for the four flights. The cars with the main group left Chanute AFB at 1630 on 7 March and arrived at Camp McCoy at 0300 on 8 March. The subjects were rebriefed on the experimental conditions and then fed their first meal of test ration at approximately 0430. They marched out to their camps and the field phase was underway. The return trip was accomplished in Pullman cars. The cars left Camp McCoy at 2100 on 21 March and arrived at Chanute AFB at approximately 1100 on 22 March. The subjects were fed at noon, reestablished in their quarters, and started on rehabilitation.

B. THE SUBJECTS

1. Selection of Subjects

The airmen used as subjects in this investigation were obtained from Lackland AFB, Texas (ATRC). The majority of these men were Airmen 3rd class, who had just completed their basic training. Prior to arrival at Chanute AFB, these airmen only knew that they had volunteered for a ration study and that the compensation was 14 days of convalescent leave. No detailed briefing had been given and the men had only met the minimum medical standards for induction into the USAF. There had been no other medical or psychological selection.

At Chanute AFB these volunteers were assigned to 3351st Student Squadron and then placed under the command of the Project Officer. Although replacements for physically unfit subjects were not available, it was decided to eliminate from the study any men whose health might be impaired by the rigors of investigation. Accordingly each man was given a complete physical examination. A chest X-ray was taken. His Forms 88 and 89 (history and physical examination) were reviewed. Four men were found to have had history of serious illness (Table II. 1) but none of these were in such a state of

TABLE II. 1

SUBJECTS WITH HISTORY OF SERIOUS ILLNESS

Subject Code No.	Diagnosis	Remarks
58	Bronchial asthma	Active but controlled by appropriate medication
62	Pulmonary tuberculosis	Healed
81	Primary syphilis	Had responded to appropriate treatment
84	Grade II systolic murmur; no history of rheumatic fever	No cardio-respiratory complaints

physical fitness that participation in the trial was contraindicated.

When the subjects were delivered to the Project Officer, one man was absent. He had gone AWOL. He was removed from the roster of subjects, for he did not reappear at Chanute AFB until late in the pre-period.

2. Handling of Subjects

Flights of Subjects. The 87 airmen were formed into four flights on a voluntary basis and the men were assigned to their flight leaders. The age, height, weight, race, and religion of these airmen and the 12 non-commissioned officers have been detailed in Tables II. 2, II. 3, II. 4, II. 5, and II. 6. Except for distribution of Negroes (N), the four flights were very similar with respect to age, height, and weight. In Flight 1 27.2% of the men were Negroes; in Flight 2, 68.2; in Flight 3, 13.6; and in Flight 4, 100.0. In Flight 1 there was one Malayan, designated Y. The flight leaders were older, taller, and heavier, on the average than the volunteer airmen (Table II. 6).

Indoctrination of Subjects. The indoctrination of the subjects was done by flights; the administrative and medical non-commissioned officers assigned to each flight attended the briefing of their respective flight. At each briefing, the project officer, the adjutant, the responsible investigator, the supervisory investigator, and the chief dietitian shared the program so that all details of the trial could be explained. The project officer and adjutant discussed such matters as command, discipline, pay, laundry, personal problems, mail, and convalescent leave. The responsible and supervisory investigators dealt with the scientific aspects of the trial; testing, collection of specimens, restrictions to be imposed, and duties. The dietitian discussed the problems of the weighed diets and measured consumption of water.

Discipline, morale, and convalescent leave: Under the conditions of the present investigation it was essential that some incentive for cooperation by the subjects be offered. The project officer was authorized to give each subject who cooperated fully with the restrictions and responsibilities

TABLE II. 2

SOME CHARACTERISTICS OF SUBJECTS: FLIGHT 1

Subject Code No.	Age yr.	Hgt. in.	Wgt. lb.	Race	Faith
1	19	65.2	125.4	Y	Cath
2	17	65.5	127.4	N	Prot
3	18	66.5	160.1	W	Prot
4	17	67.8	133.1	W	Prot
5	17	71.5	150.6	W	Prot
6	17	65.5	119.9	W	Prot
7	20	71.5	159.5	W	Prot
8	18	72.0	172.4	W	Prot
9	17	67.8	115.4	W	Prot
10	18	66.5	123.1	N	Prot
11	20	72.5	154.1	N	Cath
12	18	65.2	209.9	W	Prot
13	18	70.2	153.3	N	Prot
14	18	69.5	148.8	N	Prot
15	19	72.2	154.0	W	Prot
16	18	66.5	131.2	W	Prot
17	18	67.5	144.1	W	Prot
18	18	66.1	126.0	W	Prot
19	20	66.2	135.7	N	Prot
20	17	66.8	139.8	W	Prot
21	18	70.5	127.6	W	Prot
22	17	68.8	155.2	W	Prot
Mean	18.0	68.3	143.9		

TABLE II. 3

SOME CHARACTERISTICS OF SUBJECTS: FLIGHT 2

Subject Code No.	Age yr.	Hgt. in.	Wgt. lb.	Race	Faith
23	18	72.8	152.7	W	Prot
24	17	66.5	130.7	N	Prot
25	17	72.8	157.0	N	Prot
26	18	70.8	164.2	N	Prot
27	18	67.8	145.2	N	Prot
28	20	70.8	150.7	W	Cath
29	19	67.5	143.0	W	Prot
30	18	66.5	118.6	N	Prot
31	18	67.8	132.9	N	Prot
32	18	66.5	147.6	N	Prot
33	18	63.5	119.7	W	Cath
34	18	73.5	156.7	W	Cath
35	17	67.5	129.4	N	Prot
36	18	69.5	145.4	W	Prot
37	18	67.5	154.2	N	Prot
38	18	70.5	161.1	N	Prot
39	18	67.2	136.9	N	Prot
40	18	71.5	160.6	N	Prot
41	19	68.2	163.1	N	Prot
42	18	70.5	156.6	W	Cath
43	17	68.0	140.1	N	Prot
44	18	69.5	161.7	N	Prot
Mean	18.0	68.9	146.7		

TABLE II. 4

SOME CHARACTERISTICS OF SUBJECTS: FLIGHT 3

Subject Code No.	Age yr.	Hgt. in.	Wgt. lb.	Race	Faith
45	18	71.8	171.9	W	Prot
46	17	66.5	139.4	W	Prot
47	18	65.5	136.4	W	Cath
48	17	68.5	138.4	W	Prot
49	22	65.2	125.7	W	Prot
50	18	66.5	135.7	W	Prot
51	17	70.8	148.2	W	Prot
52	17	67.5	138.8	W	Prot
53	18	66.5	155.1	W	Prot
54	17	66.8	142.1	W	Prot
55	18	67.5	129.1	W	Prot
56	20	66.5	133.9	W	Prot
57	17	71.0	158.5	W	Prot
58	18	68.5	124.5	W	Cath
59	17	70.2	163.5	W	Prot
60	17	68.5	151.7	N	Cath
61	18	68.0	147.3	W	Prot
62	17	66.2	109.7	N	Cath
63	22	67.5	161.6	W	Cath
64	18	74.0	167.2	N	Prot
65	18	71.5	135.7	W	Prot
66	18	75.2	162.8	W	Prot
Mean	18.0	68.6	144.4		

TABLE II. 5

SOME CHARACTERISTICS OF SUBJECTS: FLIGHT 4

Subject Code No.	Age	Hgt.	Wgt.	Race	Faith
68	18	71.2	140.1	N	Prot
69	18	70.8	158.3	N	Prot
70	17	68.2	133.7	N	Prot
71	18	72.0	141.6	N	Prot
72	17	66.0	134.9	N	Prot
73	19	64.0	130.2	N	Prot
74	19	67.0	170.9	N	Prot
75	18	67.0	149.5	N	Prot
76	17	67.5	131.0	N	Prot
77	17	61.5	121.4	N	Prot
78	17	70.2	126.9	N	Prot
79	17	68.0	131.7	N	Prot
80	20	65.8	145.9	N	Prot
81	17	69.2	145.6	N	Prot
82	17	69.8	144.6	N	Prot
83	18	62.8	128.1	N	Cath
84	17	70.0	127.1	N	Prot
85	19	70.2	151.2	N	Prot
86	18	64.2	118.8	N	Prot
87	18	63.0	136.1	N	Prot
88	18	64.0	138.8	N	Prot
Mean	17.8	67.2	138.4		

TABLE II. 6

SOME CHARACTERISTICS OF SUBJECTS: FLIGHT LEADERS

Subject Code No.	Age yr.	Hgt. in.	Wgt. lb.	Race	Faith
90	41	69.0	163.0	W	Prot
91	24	74.2	202.0	W	Cath
92	22	68.8	158.0	W	Prot
93	40	67.2	138.0	W	Prot
94	24	68.8	144.0	W	Prot
95	21	71.8	194.5	W	Cath
96	37	68.8	152.0	W	Cath
97	22	71.0	145.0	W	Prot
98	22	69.5	152.0	W	Prot
99	25	71.0	161.0	W	Prot
100	33	66.0	160.5	W	Prot
101	25	68.2	133.0	W	Prot
Mean	28.0	69.5	158.7		

imposed by the supervisory investigator 14 days of convalescent leave. This incentive served as a disciplinary measure, for when subjects did not cooperate it was possible to take from them a fraction of the full leave. Application of Section XV (Uniform Code of Military Justice) punishment for insubordination, fighting, petty larceny, etc., was not possible, for the subjects were living under rigidly controlled conditions. The experience of the project officer and the supervisory investigator indicated that the incentive of leave was generally an adequate disciplinary measure. Most of the subjects, in spite of their youth and brief military experience, cooperated exceedingly well in all aspects of the experiment. Penalties against the few who failed to cooperate helped to keep the morale of the group at a high level throughout the trial and the scientific success of the project was assured.

Specimens: The subjects were required to collect all of their urine and feces. The urine was collected for 24-hour periods in uncoated, gallon-sized, tin cans, which the subjects carried with them at all times. The flight leaders maintained a log of the morning urination times. Stool specimens were collected in one quart paraffin-lined cartons (Sealright). A separate carton was used for each bowel movement. Similar cartons were to be used if any subject vomited, a rare occurrence during the test. The living quarters of the subjects and the mess hall were supplied with a quantity of these cartons. The tin cans were turned in daily at the clinical laboratory and the cartons were collected periodically by members of the test team.

Liquids and food: At Chanute AFB the subjects were allowed free but measured consumption of water. The control was accomplished by issuing daily to the subject a canteen filled with water. The canteen was refilled at the mess hall at each meal as desired and a record was made of the refills. Each morning the canteen was exchanged for a fresh filled container. Other liquids, such as cocoa, tea, and coffee, were allowed only at meal times. No food could be eaten other than that issued at the mess hall and no subject

was allowed to take uneaten food from the mess hall.

At Camp McCoy the subjects of Flights 1 and 3 were permitted unlimited water. Their canteens were refilled in the same manner as at Chanute AFB. The subjects of Flights 2 and 4 were allowed no more than 910 ml. of liquids per day. One canteen holds this volume of water. If tea or coffee was desired at meals, water from the canteen was exchanged for it. If more than 50 ml of water was used in cooking the daily food, an equivalent volume was taken from the canteen before issuing it to the subjects in the morning. All subjects turned their canteens in every morning in exchange for a fresh one. The volume of water remaining in the canteen was measured and recorded.

The only food permitted the subjects was that issued at the mess hall. Because of difficulty in adjusting to the experimental rations some of the subjects were permitted to take part of their meal to camp to complete its consumption under the supervision of the flight leader.

Personal hygiene: At Chanute AFB the men were allowed to brush their teeth daily. They were on their honor not to swallow the wash water. They shaved and washed daily but were allowed only one shower each week.

At Camp McCoy the men generally practiced the personal hygiene recommended for the castaway. They washed and shaved daily and were allowed to brush their teeth. During the first week they were permitted to use the facilities of the headquarters area but when it was discovered that a few of them were not maintaining their water restrictions, this privilege was withdrawn. Only one shower was allowed, at the end of the two-week period at Camp McCoy.

During all phases of the trial the men were responsible for the cleanliness of their clothing. They washed their own fatigues, underwear, and socks.

Medical care; sick and emergency leaves: While at Chanute AFB, daily rounds were made by the medical officers. Some of the subjects developed upper respiratory infections, especially during the first two weeks at Chanute AFB. These men were confined to their barracks and given appropriate therapy. Collections were maintained and feeding was supervised by the flight leader or the medical NCO assigned to the flight. If hospitalization was required, the subject was temporarily withdrawn from the restrictions of the project; collections were stopped and no record was maintained of the food eaten. Three men were hospitalized, but returned to the project in time to take part in all or most of the field phase at Camp McCoy. One other man was hospitalized during the last week of the project. Several subjects had dental extractions before going to Camp McCoy. The surgery did not interfere materially with the continuance of the metabolic regimen. Generally only one meal was missed and then the subject began eating as usual.

One subject withdrew from the test during the second week at Chanute to visit his family on emergency leave. He returned to Chanute in time to take part in the entire field phase. No records of collections were made during

the period of leave.

At Camp McCoy every morning after breakfast each medical officer held sick call for his flight. Daily rounds were also made at the campsites in the evening. The medical officers frequently spent most of the day and all night with their flights.

A dispensary was available in the headquarters area for handling subjects ill from upper respiratory infections or the experimental regimens. The base hospital at Chanute AFB was prepared to handle emergencies but this arrangement was never required. One dental emergency was handled by a dentist in Sparta, Wisconsin, where an extraction had to be performed. Some of the subjects developed acute upper respiratory infections and were given appropriate therapy. There were no surgical emergencies.

Special instructions for field phase: When the subjects arrived at Camp McCoy, a second briefing session was held. The entire body was addressed by the project officer, supervisory investigator, and chief dietitian. On this occasion the instructions given previously were re-emphasized and the special problems to be faced in the several experimental regimens were explained. Those men to be on limited water were instructed to ration water intake. It was pointed out that all food issued had to be eaten; there would be no seconds and no weigh-backs. Only limited alterations could be made in the nutrient mixtures, such as, manner of cooking the meat bar and variations in the candy items of the high carbohydrate regimen.

Duties of the Flight Non-Commissioned Officers. The many instructions given to the subjects were implemented by the three flight non-commissioned officers assigned to each of the four flights. A listing of their responsibilities serves to summarize the restrictions and duties of the subjects.

1. Control of subjects
   a. Complete collection of urine and feces
   b. Accurate labelling and timing of specimens
   c. Accurate records of water consumption
   d. Only food issued at mess hall may be eaten
   e. Prompt reporting for testing procedures

2. Messing
   a. Tray check for each man in flight
   b. Supplying subjects with seconds when allowed and recording same
   c. Observation of eating
   d. Participation in weigh-back operation

3. Testing
   a. Participation in some tests as regular subjects
   b. Responsibility for conduct of run of half mile
   c. Daily weighing of subjects

4. Observation
   a. Daily log of flight activity
   b. Daily remarks on condition of subjects

Typical Logs of Daily Activity. Because of the large group of subjects studied in this trial, it was necessary that their daily activity be regimented and scheduled. Completion of the many tests and continuous control of the subjects would have been otherwise impractical. No detailed records or diaries of physical activity were maintained. Such records are difficult to convert into hourly caloric expenditure even when only a small group of men are involved, and it was felt that with this large group such observations would be impractical. Caloric expenditure rather could be estimated from logs of typical daily activity.

Chanute AFB: A typical day's activity for the four weeks at Chanute AFB has been presented in Table II. 7. The subjects were under the constant

TABLE II. 7

TYPICAL DAY'S ACTIVITY OF SUBJECTS:
PRE- AND RECOVERY PERIODS AT CHANUTE AFB

Time	Activity	Time	Activity
0530	Arise, void, weigh-in, and police barracks	1200	Mess
		1230	March to project area
0615	Turn in 24-hour specimen cans and collect new container	1300	Tests, instruction, or recreation
		1700	March to mess hall
0630	March to mess hall	1730	Mess
0700	Mess	1800	March to project area
0730	March to project area	1830	Instruction or recreation
0800	Tests, instruction, or recreation	2200	Lights out
1130	March to mess hall		

supervision of the flight leaders or another member of the test team and they were not allowed to leave the area of the project unless accompanied by an individual responsible for their conduct. They remained in the area unless engaged in eating, instruction, or recreation.

The subjects generally marched three times daily to the mess hall, except when meals were omitted because of function tests. They covered a minimum of approximately six miles. They marched to and from the places of instruction. They policed their barracks and the project area and they assisted with loading and unloading equipment taken to Camp McCoy. Most of the time, however, was devoted to rather sedentary pursuits.

The instruction given the subjects consisted of lectures, movies, and demonstrations on the art of survival. For recreation there were group activities, such as games, movies, and occasional sports or television; or the individual entertained himself with reading, writing letters, or washing clothes. They were allowed to participate in special religious instruction

and to attend church on Sundays.

Camp McCoy: During the two experimental weeks of the trial, the daily activity (Table II. 8) was altered considerably from that in the four weeks

TABLE II. 8

TYPICAL DAY'S ACTIVITY OF SUBJECTS:
EXPERIMENTAL PERIODS AT CAMP McCOY, WISCONSIN

Flights 1 and 2		Flights 3 and 4	
Time	Activity	Time	Activity
0515	Arise and dress	0530	Arise and dress
0530	March to headquarters	0600	March to headquarters
0630	Turn in 24-hour specimen can; collect new one; weigh-in	0615	Turn in 24-hour specimen can; collect new one; weigh-in
0700	Mess	0700	Mess
0800	Sick call	0800	Sick call
0830	March to campsite	0830	March to campsite
0930	Tests, instruction, or recreation	0845	Tests, instruction, or recreation
1100	March to mess hall	1145	March to mess hall
1200	Mess	1200	Mess
1300	March to campsite	1300	March to campsite
1400	Tests, instruction, or recreation	1315	Tests, instruction, or recreation
1630	March to mess hall	1715	March to mess hall
1730	Mess	1730	Mess
1830	March to campsite	1830	March to campsite
1930	Recreation	1930	Recreation
2000	Lights out	2000	Lights out

at Chanute AFB. Two types of survival experiences were simulated: (1) light work, such as might be engaged in by the castaway remaining close to the disabled aircraft and (2) hard work, such as might be followed by the castaway seeking to "escape and evade". Flights 1 and 2 were exposed to the latter circumstance (Figure II. 2). They marched 12 miles daily, except on days when meals were omitted because of function tests. This marching generally required about six hours per day. Flights 3 and 4 simulted the former situation. They marched three miles per day. The time required was about 1.5 hours.

In order most efficiently both to impose these work loads and to augment administrative control, the four flights were encamped according to the scheme shown in Figure II. 3. Flights 1 and 2 were placed 2.0 miles from the headquarters area; Flights 3 and 4, 0.5 mile. Three round trips daily resulted in 12 miles of marching for the former and 3.0 miles for the latter. The daily activity (Table II. 8) depended upon the length of time devoted to marching. Flights 1 and 2 had approximately four hours a day for camp details, recreation, or survival instruction, Flights 3 and 4 proportionately more. In order to maintain as sedentary an existence as possible, the subjects of Flights 3 and 4 were confined to an area with a 0.5 mile radius from their

FIGURE II. 2. FLIGHT 2 MARCHES TO HEADQUARTERS

campsites. All survival demonstrations were made within this area.

The subjects were under the constant supervision of the flight leaders and a survival instructor. Each night the medical NCO assigned to the flight slept in the field. The medical officer of the flight also frequently spent much of the day and all night with his flight.

3. Housing the Subjects

At Chanute AFB the volunteer airmen and their non-commissioned officers were housed in conventional military barracks (Figure II. 4). Two barracks were used; one flight was assigned to each of the four floors. The barracks were heated by a central heating plant in each building and warm air was forced throughout. While the buildings could be kept warm, the temperature was subject to rather wide fluctuations.

Survival was simulated at Camp McCoy. There the men were housed in pyramidal tents (Figure II. 5). Approximately eight men slept in each shelter. No heat --- other than that furnished by gasoline lanterns --- was allowed in the tents. The men slept in standard arctic sleeping bags which were laid on beds of pine branches and grass. An open fire was built in each campsite and a lean-to shelter (Figure II. 6) was set up as a wind-break. Details procured the wood for the fires and the material for the shelters (Figure II. 7).

4. Clothing the Subjects

Chanute AFB. During the four weeks at Chanute AFB the subjects wore fatigues and brogans. In rainy weather the standard USAF rain coat was worn. After the special clothing for Camp McCoy had been issued, many of the men wore the flying jacket when the weather turned cold.

Camp McCoy. Fatigues remained the basic clothing. This item was supplemented with a woolen lined cap, gloves, heavy socks, two piece woolen underwear, cotton shirt, outer pants, flying jacket, boots with felt liners, and poncho (Table II. 9 and Figure II. 8). Most of this extra clothing was worn daily by the subjects. It added materially to their body weight and increased their daily caloric expenditure proportionately. The flight NCO's were instructed to have their men dress according to the weather so that the possibility of sweating due to overdressing could be reduced.

The men did not sleep in their clothing. Prior to retiring they undressed down to their underwear and placed the clothing removed in the sleeping bag so that it would be warm when the subjects dressed the following morning.

C. PROTOCOL OF COMPLETE STUDY

1. Flights of Subjects

The 87 volunteer airmen were divided into four groups which have been identified as Flight 1, 2, 3, and 4. A representative from each flight drew lots for the designation of his particular flight. During the experimental period the four flights were submitted to the following regimens: Flight 1, hard work, unlimited water; Flight 2, hard work, limited water; Flight 3, light work, unlimited water; Flight 4, light work, limited water (Figure II. 3). At the time of indoctrination the members of the flight were informed of these experimental regimens. At this time the members of the flight drew lots for the nutrient combination they would be offered during the experimental period. Each nutrient combination was represented in each flight as described below. Each subject was given a code number by which he was to be identified during the entire investigation.

The non-commissioned officers of each flight were also given code numbers. These men were used as ration controls. They participated in all functional tests and the body water tests. A discussion of the meaning and use of the data collected from these controls will be given in the section on Statistical Methods.

2. Periods of Investigation

The winter trials lasted six weeks. There were three two-week periods: the pre-period extended from 22 February through 7 March 1954, the experimental

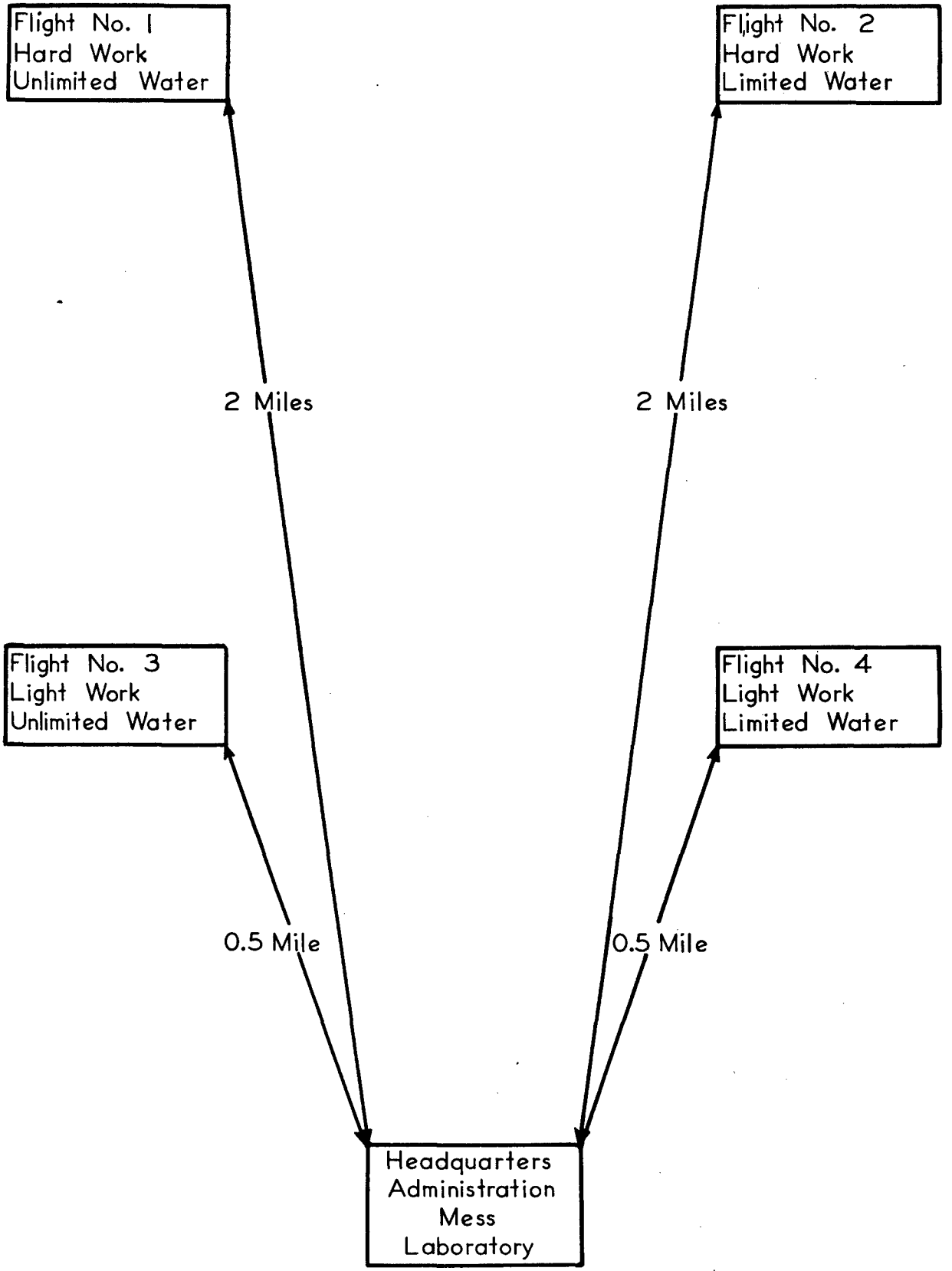


FIGURE II. 3. SCHEME FOR FIELD PHASE ORGANIZATION, WINTER TRIALS FEBRUARY-APRIL 1954.

FIGURE II. 4. CONVENTIONAL MILITARY BARRACKS USED BY SUBJECTS, CHANUTE AFB.

FIGURE II. 5. ENCAMPMENT OF FLIGHT 2 AT CAMP McCOY.

FIGURE II. 6. LEAN-TO SHELTER WITH PERSONNEL OF FLIGHT 2 GATHERED ABOUT OPEN FIRE. LEFT TO RIGHT: S/SGT. DANGLE, A/3C SANDERS, MR. KRAMER (SURVIVAL INSTRUCTOR), A/3C SALDANA, A/3C STEVENSON, A/3C GOFF, AND A/3C NORRINGTON.

FIGURE II. 7. A/3C RANCE BRINGING IN WOOD TO SHELTER AREA AT ENCAMPMENT OF FLIGHT 1.

FIG. II. 5

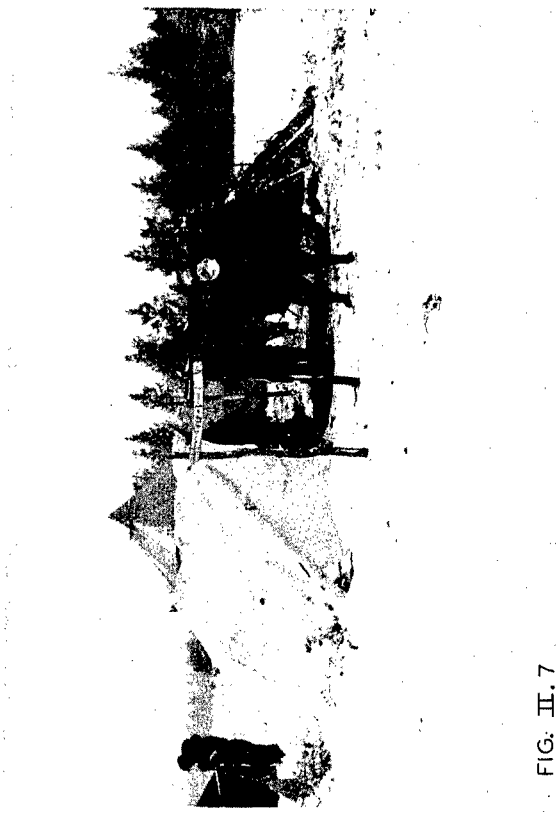


FIG. II. 7

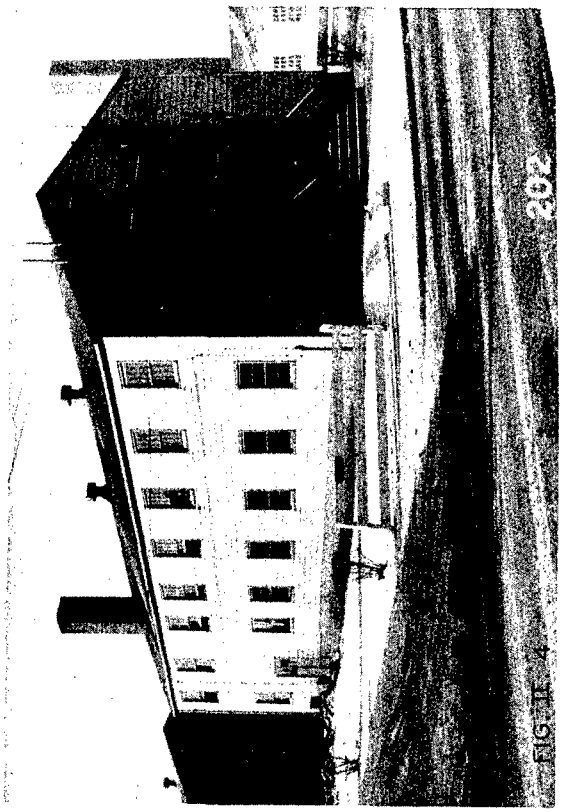


FIG. II. 4

FIG. II. 6

FIG. II 8

FIGURE II. 8. CLOTHING AND ACCESSORIES ISSUED TO SUBJECTS FOR USE AT CAMP McCOY.

TABLE II. 9

CLOTHING ISSUED FOR ENVIRONMENTAL PROTECTION DURING FIELD PHASE

Nomenclature	Weight kg	Nomenclature	Weight kg
Clothing Assembly		Accessories	
Shoe Pac, Man's	2.0	Goggle Assembly	0.1
Suspenders	0.2	Poncho	1.0
Belt	0.2	Flashlight	0.3
Shirt, Under	0.3	Knife, Fork, and Spoon	0.1
Drawers	0.3	Canteen and Cover	0.3
Trousers	1.5	Matches, Whisk Broom, Chapstick	0.2
Socks, Wool (2 pr.)	0.4	Total	2.0
Shirt, Flying	0.6		
Jacket, Flying N-2	2.6		
Cap, Field	0.2		
Glove Set	0.2		
Total	8.5		

period from 8 March through 21 March, and the recovery period from 22 March through 4 April. In the pre-period, information was collected which was to be used to judge the effects of 40 experimental regimens on the volunteer subjects. This information thus comprised the base line from which the significance of experimentally induced deviations could be evaluated. In the experimental period the subjects were subjected to predetermined regimens. In the recovery period the subjects were rehabilitated and the rate and nature of recovery from the experimental regimens were investigated.

3. Scheduling of Scientific Procedures

An extensive battery of clinical tests was conducted on 99 subjects at weekly intervals. With few exceptions the same procedures used in the temperate studies of the winter of 1953 were repeated (Table II. 10). The changes were omissions rather than additions. No tests involving an intravenous injection were performed; e.g., circulation time, antipyrine space, and thiosulfate space. There were special evaluations of acceptability or palatability. Serum bilirubin, and serum lipase were not measured nor was urinary urobilinogen. No psychometric tests were conducted and there were no measurements of possible changes in the autonomic nervous system. Serum N.P.N. was measured rather than serum urea. The only measurement added was the determination of serum alkaline phosphatase. Other details of analyses and measurements will be given in subsequent sections. The schedule followed for making these various clinical tests is shown in Table II. 11. The details of analyses, tests, and measurements will be given in appropriate sections.

4. Diurnal Cycle

It was not possible to test all the subjects at the same time of day in the case of two of the procedures. During the pre- and recovery periods the two-hour test was conducted on two consecutive afternoons: first day--- Flight 1, 1300-1500 hours and Flight 2, 1500-1700 hours; second day--- Flight 3, 1300-1500 hours and Flight 4, 1500-1700 hours. In the experimental periods, the subjects were tested all in one day, according to the nutrient regimen on which they were subsisting (see Section G: Kidney Function). The former arrangement introduced a difference between Flights 1 and 3 and Flights 2 and 4. Because many bodily processes exhibit a diurnal cycle (Kleitman, 1949), it might be that differences between flights would be explainable on this basis where statistical analysis revealed such significant variations, the question of the diurnal influence will be discussed.

The resting metabolism test was also conducted on two consecutive days. Flights 1 and 2 were tested on the first day and Flights 3 and 4 on the second day. Two whole days were devoted to this test and in case of each subject the test was done at approximately the same time of day. The subjects in Flights 1 and 3 were tested by the numbers 1 to 22 and 45 to 66, respectively; the order was reversed in the case of Flights 2 and 4; viz., 44 to 23 and 88 to 68, respectively. The flight leaders (controls) were tested in the late morning (2), early afternoon (2) and late afternoon (2) on each of the two days. By these various devices, the diurnal cycle was eliminated and the

subjects subsisting on similar experimental regimens were not all tested at the same time of day.

5. Physiological State of Subjects at Testing Times

Certain general remarks are applicable to the conditions under which the several function tests were carried out and to the status of the subjects at the time of testing.

Testing of the Subjects. The function test, physical examinations, and body water tests (D_2O) were all conducted in heated barracks both at Chanute AFB and Camp McCoy. This arrangement was adopted so that the conditions of testing would be as comparable as possible to those used by other clinical investigators. All biochemical work conducted in the field (either Chanute AFB or Camp McCoy) was also accomplished in a heated barracks.

Condition of Subjects. Because of the large number of subjects it was not possible to test the men under basal conditions. All of the tests were made on the subjects at approximately the same time of day in the case of each individual. In the cases of the resting metabolism test and the two-hour test the subjects were in a resting condition at the time of the test; i.e., they had been reclining at least 20 minutes. They were not, however, postabsorptive. Since all blood samples were obtained during the two-hour test, it is important to emphasize that the men were not always "fasting" in the usual sense of that word. In the pre- and recovery periods, subjects undergoing the two-hour test had all eaten breakfast but had had no lunch prior to the afternoon testing. In the experimental periods, men tested in the morning had had no breakfast and were therefore postabsorptive; those tested in the afternoon had had breakfast and were therefore not postabsorptive. A discussion of the possible influence of this non-postabsorptive condition on the blood levels of substances measured will be given in the appropriate portions of Section III (Results).

D. NUTRIENT MIXTURES AND DIETETIC METHODS

1. Nutrient Mixtures

As in the 1953 study two nutritional problems had to be solved in setting up the protocol for this investigation: (1) the choice of a control diet and (2) the choice of foods from which to prepare the nutrient mixtures to be studied. The final choices were based on experience gained in the 1953 study. For the most part the same foods and the same nutrient mixtures were used in 1954 as in 1953, exceptions being explained in detail below.

From the standpoint of nutrient mixtures, there were three distinct periods each with its own peculiarities; i.e., the pre-period, the experimental period, and the recovery period. In the pre-period, the subjects ate as much as they wanted of 5-in-1 ration, with no supplements. In the experi-

TABLE II. 10. OBSERVATIONS-SURVIVAL RATION STUDY WINTER 1954.

Table II. 10
OBSERVATIONS - SURVIVAL RATION STUDY
(WINTER 1954)

CLINICAL	DIETETIC	METABOLIC BALANCE	BODY COMPOSITION	CLINICAL PATHOLOGY
A. Physical Exams B. Histories C. Cardiovascular 1. B.P. 2. Pulse 3. Exercise 4. EKG D. Neurological	A. Intake 1. Gross 2. Weighback B. Menus 1. Planning	A. Energy B. Water C. Nitrogen D. Na, Ca, K E. Cl, P F. Acid-Base G. Fat Absorption	A. Weight B. Fat, LBM C. Water 1. D_2O Space 2. Water Diuresis D. Photographs E. Albright Calculations	A. Hematology B. Urinalysis C. Fecal Studies D. Blood Chemistry E. Urine Chemistry F. Blood Enzymes
LIVER FUNCTION	**ENDOCRINES**	**NERVOUS SYSTEM**	**KIDNEY FUNCTION**	**G.I. FUNCTION**
A. Cholinesterase B. Cephalin Floc. C. Cholesterol D. Blood Sugar	A. 17-KS B. Eosinophils C. Resting MR D. Blood Sugar E. Serum Na, K, Ca, P F. Cholesterol G. Blood Enzymes 1. Alk. P-ase 2. Amylase	A. Central 1. EEG B. Psyche 1. Biological Time 2. Diary 3. Progress Notes	A. Urinalysis B. Addis Count C. Creatinine Clearance D. Ammonia E. Osmotic Clearance F. Serum N.P.N.	A. Fecal Weight B. Fecal Fat C. Occult Blood D. Formed Elements E. Clinical

TABLE II. 11

PROGRAMMING OF FIELD FUNCTION TESTS

Place	Day	Date	Test Battery
Chanute AFB	1	2/22	Physicals
	2	2/23	
	3	2/24	Resting metabolism
	4	2/25	
	5	2/26	Two-hour test
	6	2/27	
	7	2/28	Physical fitness test in P.M.
	8	3/1	Resting metabolism test; E.E.G.
	9	3/2	
	10	3/3	Two-hour test
	11	3/4	D_2O on Day 10
	12	3/5	Water diuresis test
	13	3/6	Prepare to move to Camp McCoy
	14	3/7	
Camp McCoy	1	3/8	
	2	3/9	
	3	3/10	
	4	3/11	Resting metabolism test
	5	3/12	
	6	3/13	Two-hour test
	7	3/14	Physical fitness test in P.M.
	8	3/15	
	9	3/16	
	10	3/17	Resting metabolism test; E.E.G.; D_2O on Day 11
	11	3/18	
	12	3/19	Two-hour test
	13	3/20	Water diuresis test; physicals
	14	3/21	Prepare to move to Chanute AFB
Chanute AFB	1	3/22	
	2	3/23	
	3	3/24	Resting metabolism test
	4	3/25	
	5	3/26	Two-hour test
	6	3/27	in P.M.
	7	3/28	Physical fitness test
	8	3/29	
	9	3/30	Physicals
	10	3/31	Resting metabolism test
	11	4/1	
	12	4/2	Two-hour test
	13	4/3	in P.M.
	14	4/4	Water diuresis test
		4/5	End of trial

mental period, the subjects were given fixed nutrient regimens (predetermined levels of caloric intake; calories provided from protein, carbohydrate, and fat; and water intake) and they were expected to consume no more or no less than that offered. In the first week of recovery, the subjects' consumption of 5-in-1 ration was controlled for three days and ad libitum for four. No supplements were allowed at any time. In the second week of the recovery period, they were fed ad libitum from a standard garrison ration.

The nutrient mixtures are summarized in Table II. 12. There are shown

TABLE II. 12. EXPERIMENTAL NUTRIENT MIXTURES (WINTER 1954).

Table II.12
EXPERIMENTAL NUTRIENT MIXTURES
(WINTER 1954)

EXPERIMENTAL RATIONS AND OTHER FOODS USED	CALORIC INTAKE	% DISTRIBUTION OF CALORIES	SYMBOLS USED IN TABLES AND FIGURES
Pre-Period: 5-in-1	c.3200	14%P/53%CHO/33%F	PRE, Day 0
Recovery: 5-in-1 in REC I and A Ration in REC II	——	——	REC
Negative Control: Starvation	0		ST. 0
Spice Drops, Starch Jelly Bar, Hard Candy	1000 and 2000	0%P/100%CHO/0%F	0/100/0 1000 0/100/0 2000
Saltines, Oleomargarine	1000 and 2000	3%P/18%CHO/79%F	2/20/78 1000 2/20/78 2000
Meat Bar	1000 and 2000	30%P/0%CHO/70%F	30/0/70 1000 30/0/70 2000
Meat Bar, 5-in-1 Crackers, Raisins, Catsup, Jam*	1000 2000 and 3000	12%P/58%CHO/30%F 14%P/53%CHO/33%F	15/52/33 1000 15/52/33 2000 N - 3000
Ration Control: A Ration	——	——	CONTROL
Water Limited: 910 ml/day			L
Water Unlimited: ad libitum			U

* Positive Control at 3000 Cal./Day

the rations, ration components, and other foods used to formulate the several regimens, the average daily caloric intake, the percentage distribution of calories, and the water allowances. At this point the symbols to be used throughout this report in subsequent tables and figures are listed. The symbols have been set up so as to convey the maximum amount of information in a small space. For example, if a chart contains information on the relation between some physiological measure and a diet of pure carbohydrate, caloric intake 1000 Cal/day, water intake unlimited, the symbol would be "0/100/0 U 1000." The symbols are the same as those used in the temperate study of 1953, and they have been retained to facilitate comparison of charts and tables. The pure carbohydrate regimens were the same in 1953 and 1954, as were the meat bar regimens. In 1954, owing to slight changes in foods making up the nutrient mixtures, 2/20/78 was in fact 3/18/79; 15/52/33 1000 was actually 12/58/30; 15/52/33 2000 was 14/53/33; and what was called N-3000 in 1953 (i.e., 15/52/33 3000) was actually 14/53/33. In contrast to 1953, L is 910 ml of fluid per day instead of 900.

Wherever the distribution of calories is mentioned throughout this report, it has one specific meaning: the proportion of calories provided by protein, carbohydrate, and fat, respectively. It does not refer to weights of these nutrients in the diet. It was calculated by the factors 4 Cal/gm of protein, 4 Cal/gm of carbohydrate, and 9 Cal/gm of fat.

The present investigation was not concerned with the influence of vitamins on nutrient balance or functions of systems and organs. All survival rations are supplied with vitamin capsules. It is also probable that even if vitamins were not supplied, their absence would not contribute materially to the physical deterioration of the castaway if he is rescued within the two-week period over which most rescue operations continue. To avoid possible changes caused by chronic hypovitaminosis, the subjects took daily one capsule which supplied them with generous quantities of known essential vitamins. Kapseals Combex with Vitamin C (Parke Davis and Co.) were used. Each capsule contained: thiamine hydrochloride, 10 mg; riboflavin, 10 mg; vitamin B_{12}, 1 mcg; sodium panthothenate, 3 mg; niacinamide, 10 mg; ascorbic acid, 50 mg; liver concentrate (N.F.), 0.17 gm; liver fraction No. 2 (N.F.), 0.17 gm.

Rations and Ration Components of the Pre-Period. The 5-in-1 ration was used as the basic food for the pre-periods. There were several reasons for this decision. The primary one was that this particular ration offered the usual American dietary in a standard and analyzed form. A secondary reason was that the preparation of this ration would take a minimum of time, equipment, and personnel. Contained in the ration were approximately fifty items, combined into five menus (Table II. 13). Sample daily menus and recipes will be found in the report of the 1953 study.

As contrasted with the temperate study, the use of 5-in-1 ration was slightly different in 1954. Menu #2 was not used at all because, in our experience, it contained the least popular items; e.g., pork and gravy, vienna sausage, and bacon. No supplements were used, but fresh coffee and tea were substituted for the soluble coffee as being more acceptable. The salt packs

TABLE II. 13

THE FIVE MENUS OF THE 5-in-1 RATION
(Procurement of August, 1951.)

Menu #1	Menu #2	Menu #3
Beef & gravy	Pork & gravy	Beef & gravy
Ham chunks	Frankfurters	Meat balls & spaghetti
Sausage links	Bacon	Bacon
Sweet potatoes	White potatoes	White potatoes
Corn	Lima beans	Green beans
Pineapple	Apricots	Peaches
Cheese spread	Catsup	Cheese spread
Chicken noodle soup	Pineapple-rice pudding	Fig pudding

Menu #4	Menu #5	Items in All Menus
Roast beef	Beef & vegetables	Crackers
		Jam
Hamburger	Luncheon meat	
		Dry milk
Ham & eggs	Bacon	
		Soluble
White potatoes	Corn	coffee
Tomatoes	Peas	Cocoa
Pears	Fruit cocktail	Gum
Catsup	Tomato soup	Sugar
Date pudding	Fruit cake	Candy
Peanuts	Peanuts	

and sugar packs were withdrawn and Sucaryl (Abbott) was substituted. These measures were taken in order to allow an accurate estimate of the intakes of NaCl and carbohydrate. In order to insure constancy of body weights during the pre-period, any subject could have seconds of specific items: crackers, jam, milk for coffee, cocoa, tea, and coffee. There was no restriction of fluid intake.

Rations and Ration Components of the Experimental Periods. Twenty different nutrient combinations were imposed during the two experimental weeks. It was planned that two subjects (four for starvation) performing hard work and two (four for starvation) light work, would subsist on one or another of the regimen straight through a 14-day period (12 days for starvation). With only minor deviations this plan was fulfilled.

Of the 87 subjects 80 completed the full period on their assigned regimens (Table II. 14). Table II. 15 gives individual data for the seven men who were not on their assigned regimens for the full period. Subject 1 came down with the mumps on the second day of starvation; subjects 4 and 68 were taken off starvation at the end of seven days; subjects 47 and 60 were taken off their respective regimens at the end of six days. The cases of subjects 8 and 16 were different from those of the others. They became ill in the pre-period and recovered after the start of experimental periods of all other subjects. Hence they were four days late in starting their respective regimens but they did complete the last ten days in schedule with all other subjects.

In addition to the set pattern for clinical testing when a subject came off early (See section on Combined Tests.), there was a predetermined pattern also for nutritional rehabilitation. The primary consideration for taking a subject off a diet early was clinical judgement that this step was necessary for the welfare of the subject. After completion of the battery of tests and any necessary dispensary treatment, the subject was assigned to the light work unlimited water group (Flight 3). In general these subjects received 15/52/33 with daily increases of 1000 Cal until they were eating N-3000 after which they continued for the remainder of the experimental period.

The individual experimental regimens are discussed immediately following. Their physical appearance is shown in Figures II. 9-14. Sample menus will be found in the 1953 report.

Negative control starvation: The subjects were allowed water and black coffee or tea sweetened with Sucaryl (Abbott) as desired. The intake of Sucaryl varied from zero to 16 tablets per day. This substance had no demonstrable effect on ketonuria. Recently Schoenberger and his associates (1953) have reported comprehensive studies of the calcium compound ingested at 5.0 gm/day for 18 days by two volunteer subjects. No significant changes were observed in hematological values, blood chemistries, renal function, and nitrogen, sodium, and potassium balances. The calcium and phosphorus balances were attained in the expected fashion by the extra calcium consumed, (505 mg/day). Repeated physical examinations revealed no remarkable changes. The subjects noted that their stools tended to become mushy. Since our subjects

TABLE II. 14

NUMBER OF SUBJECTS AND DURATION OF EXPERIMENTAL REGIMENS*

Experimental Regimen	Flight 1		Flight 2		Flight 3		Flight 4	
	No.	Days	No.	Days	No.	Days	No.	Days
ST 0	2	12	4	12	2	12	2	12
0/100/0 1000	2	14	2	14	2	14	2	14
0/100/0 2000	1	14	2	14	2	14	2	14
2/20/78 1000	2	14	2	14	2	14	2	14
2/20/78 2000	1	14	2	14	2	14	2	14
15/52/33 1000	2	14	2	14	2	14	2	14
15/52/33 2000	2	14	2	14	2	14	2	14
15/52/33 3000	2	14	2	14	2	14	2	14
Control	3	14	3	14	3	14	3	14

*Excluding subjects failing to complete experimental period.

TABLE II. 15

SUBJECTS FAILING TO COMPLETE EXPERIMENTAL PERIOD

Subject Code No.	Experimental Regimen		Work	Days on Regimen	Remarks
1	ST 0	U	Hard	2	Mumps
4	ST 0	U	Hard	7	R.U.Q. pain, exhaustion
8	0/100/0 2000	U	Hard	10	Ill in pre-period
16	2/20/78 2000	U	Hard	10	Ill in pre-period
47	ST 0	L	Light	6	?Conversion reaction
60	2/20/78 2000	U	Light	6	?Intolerance for fat
68	ST 0	L	Light	7	Exhaustion

FIGURE II. 9. COMPONENTS OF EXPERIMENTAL REGIMENS--- STARVATION. SUCARYL (ABBOTT), FRESH TEA, FRESH COFFEE, AND WATER.

FIGURE II. 10. COMPONENTS OF EXPERIMENTAL REGIMENS--- HIGH CARBOHYDRATE (CODE A). SPICE DROPS, HARD CANDIES, AND STARCH JELLY BARS.

FIGURE II. 11. COMPONENTS OF EXPERIMENTAL REGIMENS--- HIGH FAT, LOW CARBOHYDRATE, LOW PROTEIN (CODE C). SALTINES AND OLEOMARGARINE.

FIGURE II. 12. COMPONENTS OF EXPERIMENTAL REGIMENS--- HIGH PROTEIN, HIGH FAT, LOW CARBOHYDRATE (CODE B). MEAT BAR.

FIGURE II. 13. COMPONENTS OF EXPERIMENTAL REGIMENS--- 15/52/33 (CODE D, "NORMAL MIXTURE"). MEAT BAR, CRACKERS (5-in-1), DRIED RAISINS, JAM, AND CATSUP.

FIGURE II. 14. COMPONENTS OF EXPERIMENTAL REGIMENS--- WATER (CODE U AND L). WATER AND VITAMIN PILLS.

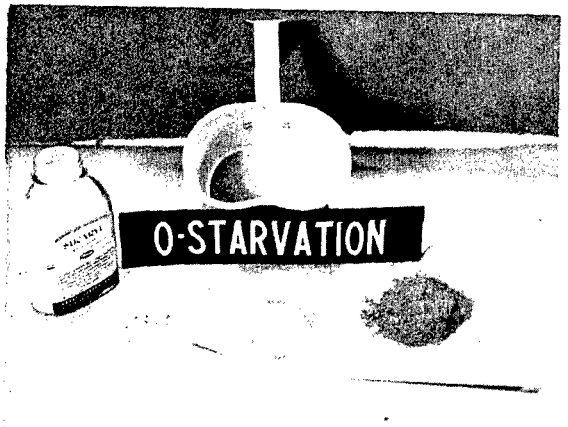


FIG. II. 9

FIG. II. 10

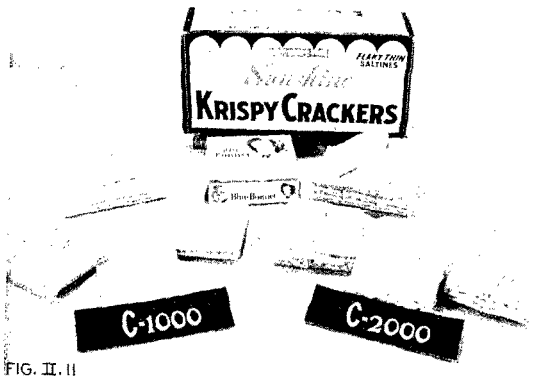


FIG. II. 11

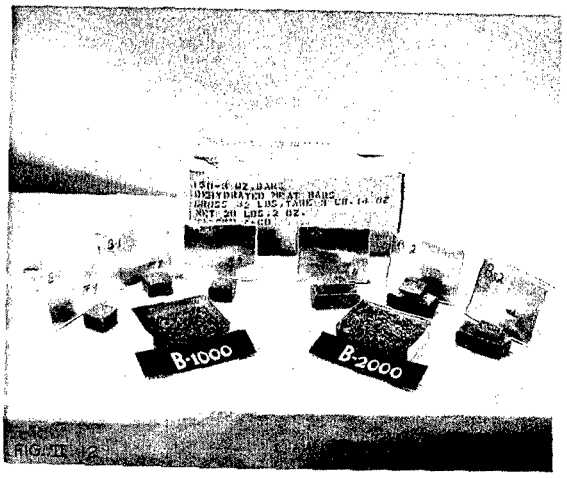
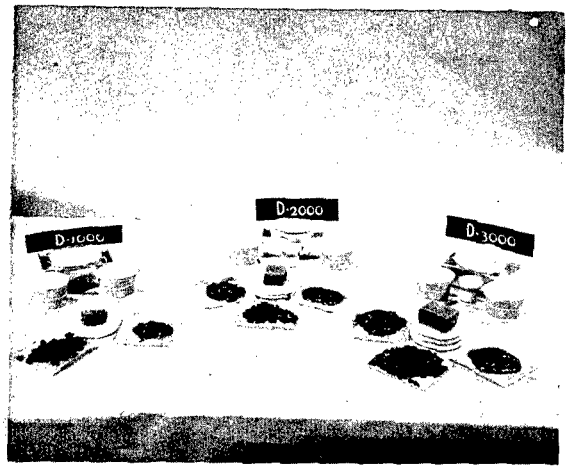


FIG. II. 12



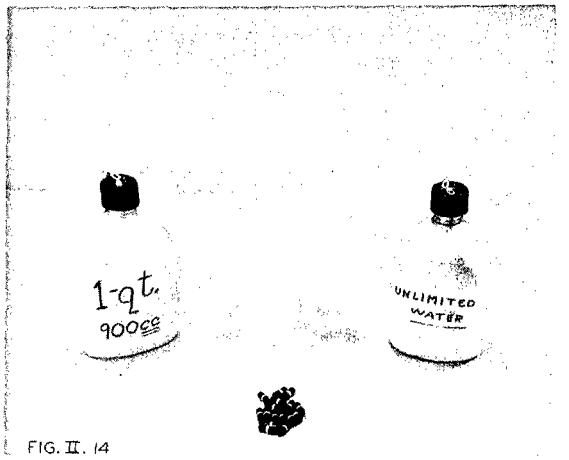


FIG. II. 14

did not ingest such large amounts of Sucaryl, it is reasonable to assume that our data likewise were not prejudiced by the use of this synthetic sweetener.

It was decided to remove all men from the starvation regimen on the twelfth day after completion of clinical testing. Accordingly, their rehabilitation actually began during the last two days of the experimental period. On Day 13 these men received 500 Cal of the 15/52/33 ration; on Day 14, 1000 Cal.

High carbohydrate (0/100/0): This ration consisted of candy items: spice drops (small spice flavored gum drops), hard candy (Life Savers), and starch jelly bars (large, bland-flavored gum bars). The subjects were allowed to determine their own combinations of these three items. Some men preferred to subsist entirely on one item, others ate various mixtures of two or three. If a change was desired, the subjects were allowed to select a new combination. Tea and coffee sweetened with Sucaryl and a daily vitamin capsule also were given the men on this regimen.

High fat, low carbohydrate, low protein (2/20/78): Oleomargarine and crackers (saltines) were the components of this nutrient mixture. The saltines were used instead of the bread unit of the 5-in-1 ration because they gave a greater surface for the large amount of oleomargarine which had to be ingested. Sample menus will be found in the report of the 1953 study.

The crackers and oleo were served as sandwiches. Some men preferred these sandwiches heated prior to eating, others preferred them cold. The only variation allowed was the warming. Tea and coffee sweetened with Sucaryl and a daily vitamin capsule were also given.

In the 1953 study an experimental chocolate bar, prepared by the Wilbur-Suchard Chocolate Company, Inc., was used. This material produced a variety of gastrointestinal symptoms ranging in severity from nausea to biliary dyskinesia. Because of the high incidence of these complaints among the eight volunteer students, this item was not included in the present investigation.

High fat, high protein, low carbohydrate (30/0/70): The basic food of this nutrient mixture was the meat bar (Ration, Special Survival). The meat bar is a form of pemmican, and is composed of 50% (by weight) of rendered beef fat and 50% (by weight) of dried lean beef (Steffanson, 1942). In this study the unflavored bar was used. Each bar weighed approximately four ounces. This bar was prepared and served in a variety of ways depending upon the desires of the subjects. Some preferred the meat bar dry, others, cooked with a small amount of water. At first a number of men tried it in both forms until they found the way most suitable to their palates. Once a decision was reached they tended to eat the meat bar in the same manner for the remainder of the experimental period. Thus, within the dictates of each man's water intake, the individual preferences were accommodated. As with all other regimens coffee and tea sweetened with Sucaryl and a daily vitamin capsule were also given.

In our experience, it required about three or four days to become accustomed to this unusual food. Certainly at Camp McCoy, the third day was climactic. At that time all the men were ready to quit because of cramps, hunger pangs, nausea, and the like. They were assured that with persistence these symptoms would abate. Because this prediction proved true and the subjects were willing to make the necessary effort, this crisis passed and the men remained on their regimens for the full 14 days.

"Normal mixture" (15/52/33): This nutrient mixture was prepared so as to approximate the percentage distribution of calories in the voluntarily selected diet of troops (Johnson and Kark, 1947). The basic items used in the 1954 winter test were: meat bar (Ration, Special Survival). bread unit (5-in-1), dried raisins, jam, and catsup. Experience of the temperate test of 1953 with the cereal biscuit (Ration, Special Survival) had indicated that undesirable gastrointestinal symptoms arise with a majority of subjects eating that item and this undesirable feature warranted discarding the biscuit in the present study. An intensive study by Pandazi and Boyd (1953, 1954) led to the development of the "normal mixture" used in this investigation. Their final ration approximated closely in composition and in actual foodstuffs the exploring rations of Peary (1910) and Amundsen (1913). Thus the ration as used in the winter test of 1954 was compact and palatable, provided the desired protein-carbohydrate-fat ratio of 15/52/33, and its fruit component, dried raisins, provided amounts of potassium and phosphorus when fed at 3000 Cal/day which the temperate study of 1953 had suggested might be very important in survival rations.

In this regimen variety was provided for by alterations in the methods of preparing the meat bar (vide supra). Tea and coffee sweetened Sucaryl and the daily vitamin capsule were allowed as for all other subjects.

Ration controls in experimental periods: As will be pointed out in extenso in the section on Statistical Methods, the present study was fortunate in having ideal ration controls. These were the twelve flight leaders who lived and worked under precisely the same field conditions as the men over whom they had supervision, but who subsisted on the best garrison ration that could be provided at Camp McCoy. It contained a wide variety of fresh meat, vegetables, fruit, dairy products, and bakery items offered in generous amounts. It should be pointed out that these flight leaders had such garrison ration in the pre- and recovery period as well.

Rations and Ration Components of the Recovery Periods. Each of the two "recovery" weeks was handled differently and they will be described separately.

Recovery week I: The basic ration was 5-in-1 without supplements. Experience with the "post-period blues" in the 1953 study indicated that uncontrolled transition from experimental regimens to a regular diet can lead in a high proportion of subjects to gastrointestinal complaints of some severity. Therefore, controlled realimentation was employed in the present study. During the first three days of this period the caloric intake was increased by increments according to the caloric deficit which the subjects had incurred in the preceding experimental period. Table II. 16 shows the

TABLE II. 16

REALIMENTATION SCHEDULE FOR FIRST THREE DAYS OF RECOVERY

Experimental Regimen	Caloric Intake in REC I		
	Day 1	Day 2	Day 3
ST O*	1000	2000	3000
1000	1000	2000	3000
2000	2000	3000	3000
3000	3000	3000	3000

*Rehabilitation begun Day 13 of EXP II.

schedule that was followed. After the third day the subjects were allowed unlimited amounts of all items in the 5-in-1 ration (except sugar and salt). Even with the great care which was exercised in this graded realimentation there were some ten episodes of acute nausea and vomiting on the first day of ad libitum feeding and a number of other subjects complained of epigastric distress. This episode lasted only 24 hours and on the fifth day all subjects were feeling fit.

Recovery week II: The standard ration for the second week was the same A ration as provided for all personnel at Chanute AFB, except that double rations were drawn. Under the circumstances only two helpings of meat per meal and four half pints of milk per meal could be allowed. There was no limit on the intake of other foods.

The procedure for Rec II was adopted for two reasons. First, it deemed desirable to insure that subjects were fully rehabilitated before departing on their bonus leaves. Second, there was a scientific reason. Substantial differences had appeared between the ration controls (flight leaders) and all the experimental subjects with respect to endocrine status. It was highly important to determine whether or not these differences could be attributed to experimental rations including the 5-in-1 as compared with a liberal garrison ration.

2. Preparation of Food

The method of serving weighed portions of food to a large number of men was determined by the need for advance preparation. In the 1953 study portions were weighed as served. This method could not be used for a large number of men. It was necessary to find a way to prepare individual portions a day in advance, to insure quick meal service, and to keep hours of work within reason. Because the site and type of building were undetermined during the planning stages, food preparation and service had to be assumed for plain barracks containing no equipment.

It was decided that small aluminum containers with lids would be used for each serving of food. In the carrying out of the actual test containers and crimpers were provided by the Reynolds Aluminum Co., Louisville, Ky., and their technical representative instructed our staff in their use. This method proved extremely workable. The containers could be filled in advance

with weighed identical portions, refrigerated or frozen, heated in ovens, and then discarded after use. They minimized the need for large equipment. The food could be portioned from the can, then refrigerated, and finally heated in ovens. Dish washing was eliminated. The actual aluminum items used throughout all phases of the study were (1) the 12-oz tray, (2) the 8-oz flat tray, and (3) the 8-oz deep tray.

Two other kinds of equipment allowed individual portioning in all phases of the investigation. The first of these was plastic wrap (Saran wrap) which was used for items such as crackers and meat bar. The second was paraffin-lined cardboard containers (Lily) of which the three kinds were (1) the 1-oz creamer with lid, (2) the 3-oz cup with lid, and (3) the 3-oz souffle cup.

Details of the preparation of the food were necessarily different in different phases of the study. They will be described in three separate sections below.

Pre-Periods and Recovery Week I. When the study was finally organized, a brand new mess hall, built for feeding 500 men, was opened for the project. Needless to say the kitchen with walk-in refrigerators and freezers, stack ovens, ranges, and the dining room and serving counter were ideally suited for the study.

In general, the required number of cans of each food were opened and mixed in a large container. Individual servings were first ladled or scooped into the aluminum containers for approximate measure; then they were weighed on Hanson dietetic scales to standard serving weights; finally, lids were labeled and crimped on (Figures II. 15 and 16). The containers were placed in the refrigerator, and were brought out when needed to be heated in ovens, and taken to the serving line, all on the same trays. This method of preparation made it possible to use an assembly line technic to turn out approximately one thousand individual weighed portions in four hours.

Because of the extensive experience in feeding men 5-in-1 ration for long periods in the 1953 study, a number of successful recipes had been developed and they were used again in 1954 as a basis for feeding the 87 subjects. Details will be found in WADC TR 53-484. In this mass cooking evaporation was kept at a minimum by use of low temperatures and minimum cooking times in sealed containers. For instance, the beef and vegetable stew and corn were put in separate closed aluminum containers in the oven, set at 275°F for 45 minutes. All recipes and combinations were prepared on the basis of the weights of the individual constituents. These weights were always made to the nearest gram. For instance, in making a beef barbeque, the ingredients, beef and gravy, catsup, and tomatoes were each weighed separately, and heated in a steam-jacketed kettle until well mixed. The actual weight of the several constituents eaten could be calculated from their percentage contribution to the mixture. In this way, the values on the proximate composition of the ingredients could be used, the only change being allowance for water loss.

The one limiting factor in the use of the 5-in-1 ration was that the

FIGURE II. 15. THE PREPARATION OF INDIVIDUAL PORTIONS, CHANUTE AFB, WINTER, 1954. FROM LEFT TO RIGHT: S/SGT. McARDLE, A/1C RICKETTS, UNIDENTIFIED AIRMAN, A/1C BRODIE, AND UNIDENTIFIED AIRMAN.

FIGURE II. 16. CRIMPING OF ALUMINUM CONTAINERS, CHANUTE AFB, WINTER, 1954. A/1C BRODIE SEALING INDIVIDUAL PORTIONS.

FIGURE II. 17. PREPARATION OF MEAT BAR, CAMP McCOY, WISCONSIN, WINTER, 1954. MRS. V. SARGENT WEIGHING MEAT BAR PRIOR TO COOKING.

FIGURE II. 18. THE PREPARATION OF INDIVIDUAL PORTIONS OF EXPERIMENTAL REGIMENS, CAMP McCOY, WISCONSIN, WINTER, 1954. LEFT MRS. J. WILLIAMS: RIGHT A/1C HILGENDORF.

FIG. II-16

FIG. II-18

FIG. II-15

FIG. II-17

analytic data available were for the complete contents of each can. This situation meant, for instance, that the water in the vegetables and the syrup on the fruits had to be used completely and in proportionate amounts in order to make reliable calculations. Although several ration components could be combined, none could be separated and used separately; e.g., meat balls from spaghetti, noodles from chicken soup stock, or fatty gravy and meat.

Experimental Weeks I and II. For the most part preparation of meals was extremely simple, except for A ration eaten by the ration controls. The individual portions of the different nutrient mixtures were prepared, weighed, packaged, and labeled 24 hours in advance (Figure II. 17), and were issued at regular meal times when the subject came to the mess hall. When cooking or heating were required, coal ranges were used (Figure II. 18).

High carbohydrate (0/100/0): No special preparation of this nutrient mixture was required. It was packed in aluminum containers and labeled.

High fat, low carbohydrate, low protein (2/20/78): This regimen was served in the form of cracker-oleomargarine sandwiches wrapped in plastic. Some of the subjects preferred these heated in the oven.

High protein, high fat, low carbohydrate (30/0/70): The meat bar was eaten in either of two ways: (1) fresh from the hermetically sealed foil wrapper or (2) cooked with a small (standard) amount of water.

"Normal mixture" (15/52/33): The meat bar was prepared as described in the preceding paragraph. The bread unit was served in plastic wrap. The raisins, jam, and catsup were served in paper cups. The items were always prepared and served separately, and, for the most part, the subjects put jam on the crackers and catsup on the meat bar. In our experience, subjects who subsist on this regimen for periods longer than two weeks prefer to make a gruel by mixing all the components and heating the mixture with small amounts of water.

Water (U and L): Water was issued in 910-ml canteens at the mess hall. When unlimited water was allowed canteens could be refilled at the mess hall. One canteen per day was allowed to subjects on limited water. Appropriate deductions were made to the nearest 50 ml for water consumed as beverages such as coffee and preformed water already in food. All canteens were turned in in the morning when an accounting was made of water not consumed.

A ration: All food served to the ration controls was identical with that prepared by the mess personnel for the scientific and administrative team. No records were kept of the food consumption by the flight leader controls, their body weights and their general satisfaction being used as evidence that they were in fact well nourished.

Recovery Week II. During this week all subjects ate food prepared by the regular mess personnel of one of the mess halls at Chanute AFB. They ate their meals in that mess hall. Individual check lists were kept of food consumed by each subject.

3. Meals and Service

There were three periods in which the meals and service were handled somewhat differently. These were the two pre-period weeks and recovery week I; the two experimental weeks; and the second week of recovery. These periods will be discussed immediately following. The three features common to all periods were that (1) the subjects received only those foods called for by the scientific protocol, (2) an accurate accounting was maintained on all food and water consumed, and (3) the actual times of meals were kept nearly constant throughout all six weeks (Tables II. 7 and 8), except when the testing protocol required missing a meal. Each day the men were fed three meals, each providing one-third of the total daily calories. The only exception was the day of the two-hour test. On these days 50% of the calories were fed at each of two meals. The vitamins were issued daily at breakfast.

Pre-Periods I and II and Recovery I. The flights marched to the mess hall as separate units under the control of the flight leaders. They arrived at specified times. The four flights did not mingle during meal times. Before each meal the dietitians and mess personnel prepared the individual portions as described in the section on Preparation of Food and arranged the various weighed servings at different stations along a cafeteria serving counter. At the end of the counter was the tray check station, where a record was made of the number of items of each type on the subject's tray. The subjects in each flight went through the cafeteria line in numerical order and had their trays checked (Figure II. 19). The men in the flight then sat down at four-man tables and ate (Figures II. 20 and 21). When seconds including canteens of water were desired in pre-periods I and II, the flight leaders obtained and recorded them and gave them to the subjects at table (Figure II. 22). In the first week of recovery requests for seconds were so frequent that the subjects themselves were allowed to go back through the cafeteria line reporting their seconds at the tray check station. After the meal was finished, the flight leader led the flight past a water station where they obtained a full canteen for the one already in their possession. Then they marched out of the mess and back to the barracks area.

An important aspect of the quantitative measurement of food consumption was the weigh-back operation. This matter was so important that special instructions were given to the subjects. They were instructed to eat, if possible, everything they took. If they had to leave part of an item---especially in the case of non-homogeneous mixtures such as stews---they were instructed to eat proportionately equally of all components so that the residue would be representative of the whole dish. After a meal was over, one flight leader and usually one subject remained behind to assist in the weighing and recording of weigh-backs (Figure II. 23). All containers, empty or containing partially eaten portions, were weighed on a Hanson scale and these weights were recorded. Appropriate corrections were made later for container-weight and partially eaten items. As part of the weigh-back operation water remaining in canteens was measured to the nearest 10 ml and recorded (Figure II. 24).

FIGURE II. 19. TRAY CHECK, CHANUTE AFB, WINTER 1954. LEFT TO RIGHT: S/SGT. CAIN, A/3C MURPHY, MRS. V. SARGENT, A/3C WALKER, A/3C ROSS, AND A/3C FIRST.

FIGURE II. 20. TYPICAL TRAY OF PRE-PERIODS AND RECOVERY WEEK I, CHANUTE AFB, WINTER, 1954. A/3C FIRST BEGINNING TO EAT A MEAL.

FIGURE II. 21. MEMBERS OF FLIGHT 1 (FOREGROUND) EATING A MEAL IN PRE-PERIOD, CHANUTE AFB, WINTER, 1954.

FIGURE II. 22. FLIGHT LEADERS SUPERVISING SECONDS OF MEMBERS OF FLIGHT 4, CHANUTE AFB, WINTER, 1954. STANDING: A/1C WILSON AND S/SGT. DICKEY. SEATED: SUBJECTS OF FLIGHT 4.

FIG. II. 20

FIGURE II. 23. WEIGH BACKS AFTER A MEAL, CHANUTE AFB, WINTER, 1954. MRS. V. SARGENT AND S/SGT. CAIN WEIGHING AND RECORDING PARTIALLY EATEN PORTIONS FROM TRAY OF SUBJECT 2.

FIGURE II. 24. RECORDING WATER RESIDUUM IN CANTEEN. MRS. V. SARGENT AND UNIDENTIFIED AIRMAN MEASURING WATER IN PHARMACEUTICAL GRADUATE.

FIGURE II. 25. ISSUING FOOD TO SUBJECTS OF FLIGHT 3. IN EXPERIMENTAL PERIOD, CAMP McCOY, WISCONSIN, WINTER, 1954. LEFT TO RIGHT: MRS. V. SARGENT, A/3C GILDERSLEEVE, A/3C SADA, A/3C ABERCROMBIE, AND A/3C EDWARDS.

FIGURE II. 26. MEAL TIME DURING EXPERIMENTAL PERIOD, CAMP McCOY, WISCONSIN, WINTER, 1954. FOREGROUND: MEMBERS OF FLIGHT 4.

FIG. II. 24

FIG. II-26

Experimental Weeks I and II. At Camp McCoy the subjects were fed in a heated mess hall. They filed in by the numbers and sat by flights. They were under the constant supervision of the flight leaders and dietitians during meal times. They spent approximately three hours per day in the mess hall. The technics of preparing, issuing food, water, and vitamins, recording, and weigh-back were very similar to those at Chanute AFB with such minor modifications as were demanded by local circumstances (Figures II. 25 and 26). The chief differences at Camp McCoy were somewhat primitive equipment, an old fashioned mess hall with 8-man mess tables, and the requirement of limited water for half the subjects.

During each of the experimental weeks, two subjects on each regimen were allowed water ad libitum, the other two, 910 ml of water/day, including the water in the ration when that exceeded 50 ml. The water in the ration varied from 30 ml in the high carbohydrate diet to 255 ml in the "normal mixture" at 3000 Cal. When the subjects were on limited water, they were allowed to determine how and when they consumed the 910 ml allowance.

Recovery Week II. In this week the scientific protocol called for feeding the subjects liberal amounts of a mixed diet of fresh and frozen foods in quantities sufficient to satisfy their needs. The plan was accomplished by feeding them in a regular mess in which regular mess personnel prepared and served A ration cafeteria style. Individual tray checks were made. Uneaten foods were listed as single items (e.g., slices of bread) or parts of portions (e.g., one-half a potato) and deducted from the original servings. In general there were only minimal uneaten portions. There was no restriction on fluid consumption. Canteens were issued and unused water recorded as described above. Daily vitamin capsules were dispensed as usual.

4. Calculations

Forms for Recording Original Data and Calculations. A number of special forms were devised for specific use in this study. They ensured reliability and facilitated the thousands of arithmetical calculations required in the breakdown of the daily food intake into its several nutrients. Sample forms different from those used in the temperate study of 1953 are collected in Appendix VI.

Daily order sheet: This listed subjects' names, the diets they were to receive, and any special orders from the medical officer. This was issued to the flight leaders and the chief dietitian as needed.

Daily master menu sheet: This listed day's food for all subjects in menu form. The foods in the pre- and recovery periods were listed by name only, while for experimental diets the amounts of each food for each subject were indicated. On this sheet were also noted any general changes in the dietary regimens of the pre- and recovery periods, water-concentration factors, and sample mixtures (such as portions) which did not require special recipes.

Individual intake sheets: For each flight of 22 men there was a daily intake sheet on a clipboard. Food planned for the day was listed together

with blank spaces for extra food. An observer recorded the items on the trays in appropriate columns. Seconds, additional food, and liquids were recorded by the flight leaders. When the meal was completed, an observer recorded the weigh-backs of each partially eaten portion. For each day the amount eaten was calculated (by adding original weight and seconds and subtracting the weigh-back) and the fluid intake totaled.

Individual daily dietary analysis form: From the intake sheets the amounts of each food eaten were listed as grand totals for the day. For example, several figures for the intake of crackers were totaled and listed as one value. A vegetable, such as peas, if used plain and in a recipe, was listed as one total figure. The data on the intake sheets and the analysis sheets were double checked for accuracy. On each of these three forms the dietitians did all of the computing and transferring of data.

After the total amount of each item consumed had been listed on the analysis sheet, clerical help was used to copy the analysis from specially prepared food tables and to total the daily intake. The dietitians checked each total for accuracy, using the factors of 4-9-4 Cal/gm of carbohydrate, fat, and protein, respectively, to check against total Calories.

Individual summary sheets: The totals of each day's intake for each diet period were listed on this form. From these figures the dietitians made the averages for any period under consideration.

Gram analysis sheets: The dietitians prepared analytical tables for each food used. The basic data for preparing these analytical tables were obtained from the following sources:

1. Q.M. Food and Container Institute: Record of Nutritive Values. Ration Small Detachment, 5-in-1. MIL-R-10754. 11 December 1950. (Summary sheet, Menu #1, Menu #2, Menu #3, Menu #4, Menu #5). Washington, D. C. 1 May 1951.

2. Q.M. Food and Container Institute: Tables of Nutritive Value of Ration Items. April 1951.

3. Bureau of Human Nutrition and Home Economics, U. S. Dept. Agriculture: Table of Food Composition for the Armed Forces. Washington, D. C. (undated but current).

4. Bowes, A deP., and Church, C. F.: Food Values of Portions Commonly Used. 7th Ed. College Offset Press, Philadelphia, Pa., 1951.

The data published by the governmental agencies (1, 2, and 3) were used in calculations of the components of the 5-in-1 ration and the components of the survival rations. The data available were for calories, water, protein, carbohydrate, fat, and calcium. Since it was also necessary to know the intake of sodium, potassium, chloride, and phosphorus, this information was obtained by direct chemical analyses of representative samples of the several

components and local water supplies (see Tables II. 17 and 18 below). The data of Bowes and Church (1951) and individual manufacturers and information obtained by our own chemical analyses provided values for special food (e.g., raisins and catsup) and for all the dietary intakes of Rec II. The information contained in the paper by Bills et al. (1949) provided valuable reference for checking the data we obtained on the electrolytes in food.

All figures for the gram-analysis sheets were calculated from 100-gram portions, values being carried to one decimal point. Each item was then calculated per gram to the nearest whole gram figure. The total grams listed varied from the bread item, giving data from one to 700 gm, to milk powder, with data from one to 50 gm. The tables were enlarged from time to time to give data for larger servings than had been anticipated before the study began. These gram tables made it possible for clerical workers to list the analysis of each item on the individual sheets prepared by the dietitians. It provided a method of rapid analysis with minimum time on the part of the dietitians.

Special Devices of Calculations. In the case of some foods special procedures were adopted for standardizing the calculations. These standard procedures were:

Milk: The data sheet listed values for the dry milk powder, the dilution having been standardized as 100 gm of milk to 100 gm of water. On the daily intake sheets, the dietitians reduced the figure by half to obtain the weight of dry powder. The remainder was added to the water intake column. On the daily analysis sheet the total for the day was listed as the dried milk.

Soups: The two soups in the ration were listed in the data sheets in concentrated form. Unless used as part of a recipe, the soups were always diluted with an equal amount of water. On each intake sheet, therefore, the figures for soup were divided in half. The water was recorded in the water intake column.

5. Chemical Analysis of Food

In the temperate study of 1953, all of the military ration components had to be analyzed for sodium, potassium, phosphorus, and chloride, there being no figures available on their proximate compositions (Sargent et al., 1954, Section II C 5). For the present winter study, the same ration components were used for the experimental regimens as in 1953. Hence, analytical data from 1953 could be used. The data for sodium and potassium in 1953 were not deemed reliable, the cause probably being inefficient ashing, with volatilization and loss of sodium and potassium. Therefore, these analyses were repeated for all foods used in 1954.

Preparation of Food for Analysis. An improved method for aliquoting foods was used (Johnson, Pandazi, and Sargent, 1954). The same machine and the same method was used as for feces (Section II E 3). The whole can, or other portion, was weighed and added to the grinder. A measured volume of distilled water was

added, and the whole was homogenized and kept mixed while portions of the fluid mixture were added to bottles for storage prior to ashing.

Ashing Prior to Analysis of Sodium and Potassium. Study of the literature led to the conclusion that the best recoveries of sodium and potassium were to be achieved by rigorous attention to the temperature and time of ashing. For present purposes, suitable aliquots of the homogenized fluid mixture, usually 5 ml, were added to 30 ml porcelain crucibles by means of a calibrated Luer-Lok syringe, fitted with a 14-gauge 4-inch hypodermic needle. The homogenate was dried at 90°C overnight, and was then muffled for exactly 4 hours at 550°C, no higher. The crucible was removed and cooled, and the ash taken up in 100 ml of warm 0.1 N Hcl to which lithium nitrate was added as internal standard prior to flame photometry.

Flame Photometry. Sodium and potassium were estimated by means of a Baird Associates Flame Photometer, Serial No. DB3-508. Analysis was carried out exactly as described in their manual (Baird Associates, 1953), and suitable standard curves were run every morning and afternoon.

Calculation of Results. The basic equation for calculation was

$$\text{Na, mg/100 gm food or K, mg/100 gm food} = \frac{(\text{gm food} + \text{ml water}) \times (100) \times (\text{mg \%, photometer})}{(\text{gm food}) \times (\text{ml aliquot})}$$

Validation of Method. The ashing was validated by experiments involving samples of lima beans or vienna sausage, with or without added standards, and with times of ashing varying from 4 to 12 hours. The method of grinding and aliquotting was validated by analyzing lima beans or vienna sausage, with or without known amounts of potassium or sodium added to the original food. Under the conditions finally chosen, recoveries in both sets of experiments were within 10% of theory; results, however, are still sometimes erratic on occasion. When duplicates do not check, the whole procedure is repeated, starting with the homogenized food.

Results. Table II. 17 gives data for the sodium and potassium content of all foods used both in the 1953 temperate study and in the 1954 cold weather study. These values in 1954 were acceptable by our standards, and were of the same order of magnitude as reported in Bills et al. (1949). As had been suspected, in 1953 the values for sodium and potassium were erratic, and usually low, because of technical errors in ashing. The new and accurate data enabled us to recalculate the results for 1953.

For computation of sodium and potassium balances, the analytical values of 1954 were used for computing the intakes in the cold weather tests of 1954.

Water for drinking and that used in the preparation and cooking of food was local tap water at Chanute AFB and Camp McCoy. Representative samples for each week were analyzed for calcium, chloride, phosphorus, potassium, and sodium by our standard chemical procedures (Table II. 18). These values were

TABLE II. 17

COMPARISON OF SODIUM AND POTASSIUM ANALYSES: FOOD-1954 VS. 1953

Food Item	Sodium mg/100gm 1954	1953	%	Potassium mg/100gm 1954	1953	%
A. 5-in-1 Components						
Meat Products						
1. Pork & gravy	632	170	27	218	10	5
2. Hamburgers & gravy	592	149	25	149	10	7
3. Pork sausage links	726	190	26	242	10	4
4. Ham chunks	1312	550	42	261	15	6
5. Vienna sausage	1398	690	49	66	25	38
6. Beef & vegetables	442	225	51	135	15	11
7. Pork luncheon meat	1510	1080	71	176	85	48
8. Chopped ham & eggs	815	475	58	147	25	17
9. Roast beef	969	950	98	138	65	47
10. Beef & gravy, type II	598	375	62	221	75	34
11. Spaghetti & meat balls	814	510	63	224	115	51
12. Bacon, sliced	1240	2440	197	101	320	320
Vegetables						
1. Lima beans	315	150	47	222	175	79
2. Tomatoes	108	65	60	169	190	112
3. Peas	369	350	95	46	110	239
4. Green beans	206	155	75	44	45	102
5. Sweet potatoes	33	25	76	171	80	47
6. White potatoes	242	320	132	319	100	31
7. Corn	340	50	15	205	65	32
Desserts and Fruits						
1. Pineapple-rice pudding	117	35	30	47	55	117
2. Apricots	31	5	16	57	20	35
3. Pineapple	15	10	67	78	30	39
4. Fruit cocktail	11	5	46	11	60	542
5. Fig pudding	213	160	75	238	185	78
6. Peach halves	63	10	16	53	0	0
7. Date pudding	210	130	62	260	275	106
8. Fruit cake	182	115	63	208	160	77
9. Pears	17	5	29	0	0	100
Soups & Beverages						
1. Tomato soup, condensed	790	640	81	307	190	62
2. Chicken noodle soup	765	565	74	31	35	113
3. Powdered milk (soluble)	387	225	58	825	730	89
4. Cocoa beverage powder	492	3400	--	1058	1130	--
Bread & Cereals						
1. Bread unit	1190	915	77	169	70	41
2. Cereal bar, type B	536	610	114	560	15	3

TABLE II. 17 (CONT'D)

Food Item	Sodium mg/100gm 1954	Sodium mg/100gm 1953	Sodium %	Potassium mg/100gm 1954	Potassium mg/100gm 1953	Potassium %
Candies, Spreads, Misc.						
1. Caramel nougat	227	100	44	206	45	22
2. Tootsie Roll	167	125	75	84	55	65
3. Sweet chocolate bar, type XII	116	80	69	221	45	20
4. Cocoanut bar	204	not used	--	252	not used	--
5. Gum	10	15	150	0	20	--
6. Cheese spread	1211	1380	114	64	35	55
7. Peanuts, salted	863	280	32	637	380	60
8. Jam, cherry, plum, strawberry	22	10	45	7	50	(711)
9. Jam, grape & peach	45	---	--	23	--	--
10. Catsup	856	820	96	366	400	109
B. Components, Other Rations						
1. Meat bar	738	280	36	646	85	13
2. Cereal biscuit	353	410	116	299	100	33
3. Experimental chocolate bar	34	0	0	69	0	0
4. Candies (spice drops, etc.)	21	0	0	0	0	0
5. Pre-fried bacon	1425	1400	98	262	210	80
C. Special Supplements						
1. Horseradish sauce	(856)[1]	790	92	(366)[1]	380	104
2. Tomato sauce	(856)[1]	870	102	(366)[1]	370	101
3. Ice cream	89	45	51	60	100	167
4. Bread	546	330	61	117	55	47
5. Flour	22	5	23	44	85	193
6. Bouillon cubes	23900	510	--	1250	105	--
7. Starlac (Borden's)	682	400	59	1320	1260	95
8. Orange juice, frozen	70	10	14	406	480	118
9. Oleomargarine	1019	935	92	30	15	50
10. Saltines	1122	1270	113	132	70	53
11. Raisins	121	not used	--	429	not used	--
12. Dried apricots	88	"	--	967	"	--
13. Bouillon soup (Campbell's)	700	"	--	106	"	--

[1]Values assumed to be same as for tomato catsup, the chief component of these sauces.

TABLE II. 18

MINERALS IN WATER AT CHANUTE AIR FORCE BASE AND CAMP McCOY

Mineral	Place and Week						
	Chanute AFB				Camp McCoy		Mean
	PRE I	PRE II	REC I	REC II	EXP I	EXP II	
Calcium, mg/liter	16	11	22	15	15	18	16
Chloride, mEq/liter	0	0	0	0	0	0	0
Phosphorus, mgP/liter	0.4	0.2	0.4	0.2	0.3	0.5	0.3
Potassium, mg/liter	4	4	5	4	3	3	4
Sodium mg/liter	13	2	51	33	7	26	22

applied to the summary sheets once the daily water intake had been summated. In view of the small variation from time to time and place to place, except for sodium, and in view of the small contribution made by these minerals in the water to subjects' daily intakes, the means for all six weeks were used in calculations, chloride and phosphorus not being taken into account at all. Their contribution was negligible.

6. Palatability and Acceptability

The present study was not designed to obtain information on acceptability or palatability. The whole experimental design was aimed at providing specific combinations whose effects on the subjects could be studied. Considerations of acceptability and palatability did, however, play an important part in components selected to make up the experimental mixtures. For instance, the pork and gravy item of the 5-in-1 Menu #2 and the experimental chocolate bars and cereal biscuits used in 1953 were not utilized in part because of these considerations. In pre-periods I and II and Rec I all subjects were on the 5-in-1 ration and perhaps some idea of preference could be obtained from their choice of seconds. In experimental weeks I and II 80 of the 87 subjects never received more than one regimen. Hence, no valid conclusions could be drawn on their preferences for experimental rations.

We do not consider that habituation played a part or could be studied in this investigation because the subjects' experience was of such short duration.

E. COLLECTION AND PRESERVATION OF SPECIMENS

Three types of specimens were collected: (1) food, (2) excreta (urine, feces, and vomitus), and (3) blood. Each was handled in a standard fashion.

1. Food

Five-In-One. Each of the packaged items of food was set aside for chemical analysis. No special methods of preservation were required, for chemical analysis was begun immediately after the components were opened.

Other Ration Components and Commercial Foods. Most of the components of the experimental diets were the same as used in the investigations of 1953. Since most of the items were packaged, no special methods of preservation were required. Chemical analyses were done when other analytical data from other sources were not available.

2. Urine

Twenty-Four Hour Specimens. A 24-hour specimen of urine was collected from each of the 87 volunteer subjects daily. The collection periods extended from approximately 0530 to 0530 hours. Each day each subject was provided with a labelled one-gallon uncoated tin can, which he carried with him at all times. Coated cans were not available due to a strike in the canning industry at the time of procuring supplies. No preservative was added to the can. Prior validation studies had shown that storage of urine in such tin cans had no deleterious effect on such organic compounds as 17-ketosteroids and creatinine. (See section on Validation of Methods.) The tin cans were turned in the following morning at the Clinical Laboratory (Figure II. 27). Periodically during the three periods the controls also collected 24-hour specimens of urine.

Handling of 24-hour specimens in the field: The labels were checked, the screw-caps were tightened, and the cans were placed in convenient carrying cases (Figure II. 28). From Chanute AFB they were delivered by truck to the University within two or three hours after receipt at the laboratory. From Camp McCoy, the daily specimens were conveyed by truck to LaCrosse, Wisconsin, air-lifted in a B-25 to Chanute AFB (Figure II. 29), and then delivered to the University within eight hours after receipt at the laboratory. On only two occasions was it necessary to delay the shipment of specimens 24 hours because weather grounded the aircraft.

Handling at the University of Illinois: The volumes of the specimens were measured, and then the urine was diluted, mixed and aliquoted as follows:

Orig. Vol.	Final Vol.	Aliquot for 6-Day Pool
ml	ml	ml
100 - 999	1000	100
1000 - 1999	2000	200
2000 - 2999	3000	300
3000 - 3999	4000	400
4000 - 4999	5000	500
5000 - 5999	6000	600

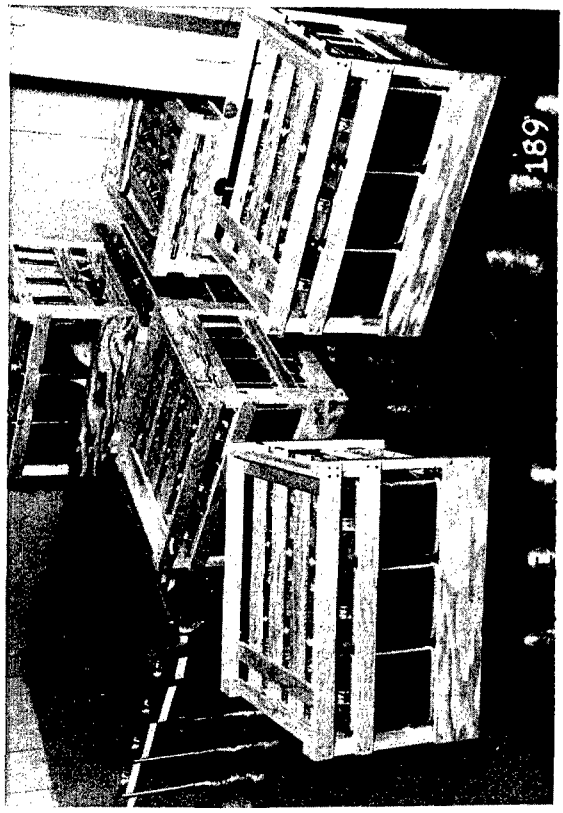
The aliquots were transferred to gallon-sized brown glass bottles and toluene was added as a preservative. A six-day pool was prepared (Figure II. 30). Each week, the 24-hour specimens collected on the day of the water

FIGURE II. 27. A/3C FORD AND A/3C J. H. ARMSTRONG DELIVERING 24-HOUR SPECIMENS TO THE CLINICAL LABORATORY.

FIGURE II. 28. CARRYING CASES FOR TRANSPORT OF 24-HOUR SPECIMENS.

FIGURE II. 29. LOADING THE B-25 AT LaCROSSE, WISCONSIN.

FIGURE II. 30. DR. IRA LICHTON PREPARING POOLED SPECIMENS FROM 24-HOUR URINARY SPECIMENS.


189

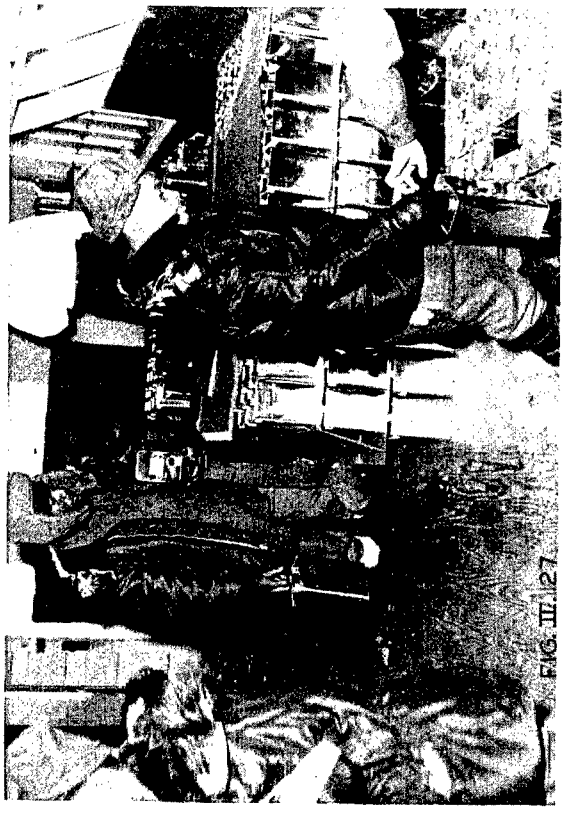
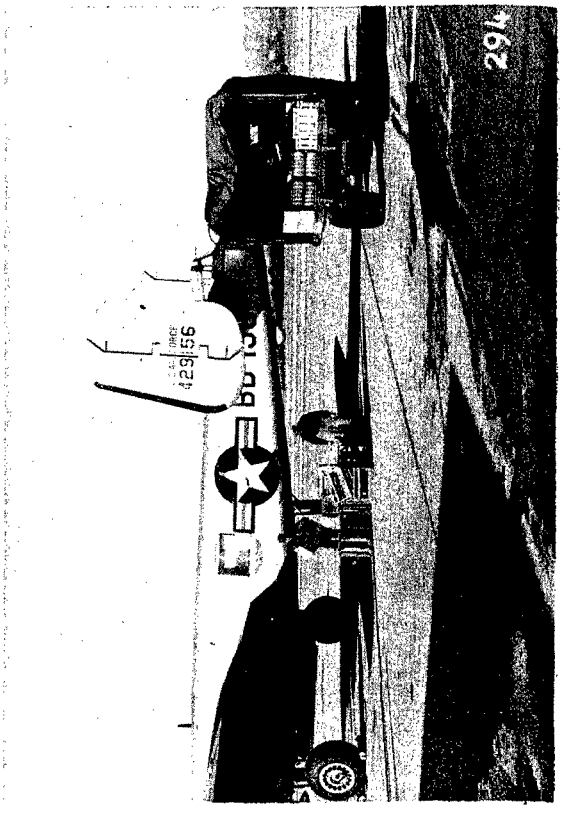


FIG. III 27


294
429 56

diuresis test or on the day of the half mile run were discarded.

On certain days an aliquot of raw urine was taken prior to dilution. These days were (1) the day prior to administering heavy water, (2) the day when heavy water was administered, and (3) the day after administering heavy water. An aliquot of 50 ml was taken, a volume which did not significantly alter the analytical data obtained from analyzing the six-day pools. The 24-hour specimens obtained from the control subjects were not diluted and pooled specimens were not prepared.

If a subject was taken off the experimental regimen early, the pool was closed and a new pool started. The latter was closed at the end of the regular six-day interval; thus two pooled specimens were prepared during the week a subject discontinued a diet early.

The pooled specimens were stored at room temperature until the six-day period was completed. At this time the individual specimens were carefully mixed and appropriate aliquots were transferred to one-ounce screw-capped brown glass bottles. All aliquots except those for 17-ketosteroids were stored at -25°F until they were analyzed. During the course of the analyses the specimens under study were maintained in standard refrigerators. The aliquots for 17-ketosteroids were kept at all times in the refrigerator.

Aliquots of diluted specimens from each of the subjects were set aside for special analysis on the last two days of the pre-period, each day of the experimental period, and the first two days of the recovery periods.

Two-Hour Specimens. Once a week an exactly timed specimen of urine was obtained during the two-hour test. These specimens were collected in one-pint uncoated tin cans.

Handling in the field: The volume was measured, and a ten-ml aliquot was withdrawn, nine of which were returned after completing the Addis count. The screw caps were tightened, the labels were checked, and the cans were packed in boxes for delivery to the University by the same courier system described above.

Handling at the University of Illinois: The volume was remeasured. If the volume was less than 200 ml, the specimen was diluted to 200 ml. When the volume exceeded 200 ml, no dilution was made. Aliquots of the two-hour urine were not added to the six-day pool. Appropriate aliquots were transferred to one-ounce brown glass bottles and stored at -25°F until chemical analysis was performed. During chemical analysis, the specimens under study were maintained in kitchen electric refrigerators at about 4°C.

3. Feces

The 87 subjects were instructed to place individual bowel movements in separate one-quart paraffin coated containers (Sealright). After use the containers were labelled with subject's code number and date and stored in designated areas of the testing site. The specimens were collected peri-

odically by members of the test team, sorted according to number, and stored in an unheated building until the time of pooling and aliquoting.

Marking Collection Periods. Once a week, and when an experimental regimen was discontinued early, each subject was given two number 000 gelatin capsules filled with powdered carmine (500-600 mg). The carmine served to mark the beginning and ending of seven-day periods.

Frequently on the low caloric diets, the subjects passed fecal specimens at such irregular intervals that it was not possible to collect a regular seven-day specimen. Rather than give the subjects an inert, bulk former such as methylcellulose or agar---which would have made it difficult to study gastrointestinal function---the carmine markers were used to identify the periods over which the collections extended. This arrangement made it possible to assign all the specimens to the correct periods of each phase of the experiment.

Pooling and Aliquoting. The daily specimens of feces were weighed, and separated according to appearance of carmine-marked stools. The feces was transferred to a homogenizer designed (Johnson, Pandazi, and Sargent, 1954) especially for the tests (Figure II. 31). This unit consisted of a commercially available garbage disposal unit and butter-churn mounted and connected together as shown. A spiggot was attached to the base of the butter-churn, through which aliquots were obtained and rinsing was accomplished. The feces was mixed with 6000 ml of tap water after grinding in the garbage disposal unit, the water being passed through the funnel to assure adequate rinsing. After mixing, appropriate aliquots were taken in one-ounce brown glass bottles. All pooling and aliquoting was accomplished in the field.

Transportation and Storage. The fecal aliquots were stored in wood blocks in commercially procured foot lockers. Periodically these lockers were shipped to the University by the established courier system. At the University the specimens were checked in and then stored at -25°F until chemical and microscopic analysis was undertaken. During the period when they were needed for analysis, the specimens were kept in a refrigerator at about 4°C.

Tap Water. Appropriate specimens of tap water used to dilute fecal specimens were saved for chemical analysis.

4. Blood

Venipuncture. All specimens of blood taken during the two-hour test were obtained by venipuncture, stasis being maintained in all cases. This procedure was required because, when the subjects were on a regimen of limited water and low calories, the veins were frequently collapsed, were difficult to enter, or would contract after a successful puncture. All the venipunctures were made with sterile 18- or 19-gauge needles and the blood was drawn into sterile syringes of appropriate size. Ethyl alcohol (70%) was used to cleanse the skin surface, which was wiped dry with sterile cloth prior to the puncture.

Whole Blood. This type of blood was used for several analyses. Smears

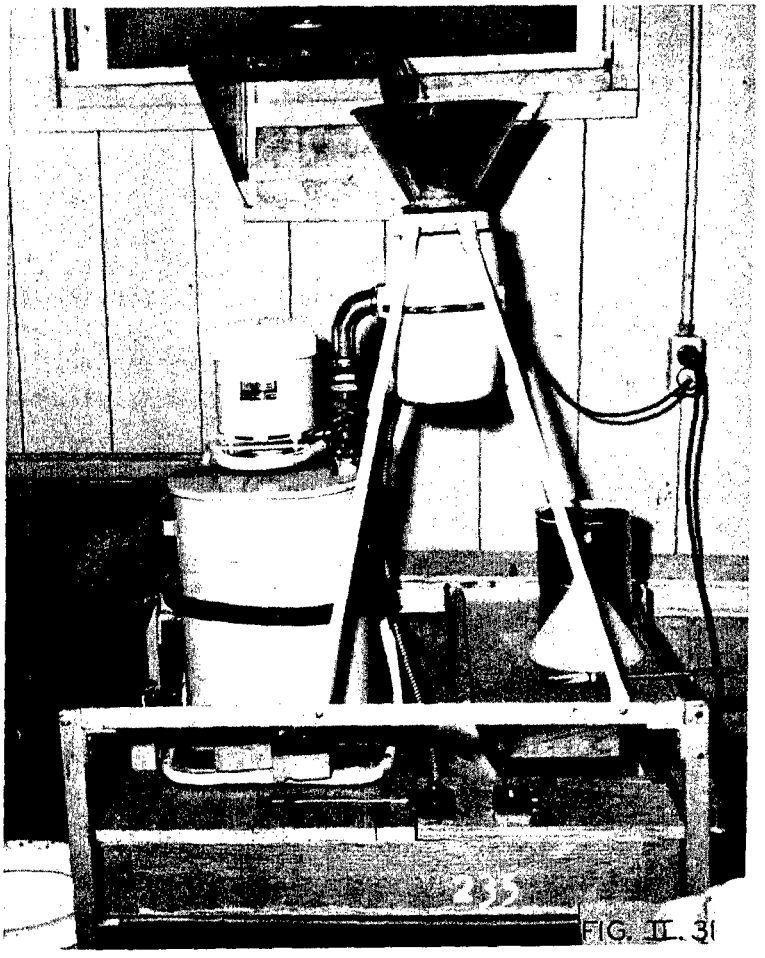


FIGURE II. 31. HOMOGENIZER-MIXER FOR FOOD AND FECES.

for differentials were prepared by placing the first few drops of blood from the needle on glass slides. Blood placed in screw-capped vials containing dry double oxalate (sodium and ammonium oxalate prepared according to the formula of Hepler, 1949) was used for hematological analyses (sedimentation rate, hematocrit, and white blood cell counts) and chemical analyses (glucose). All these analyses were carried out within a few hours after drawing the blood.

Serum. All other chemical analyses on blood were made on serum. The serum was obtained by allowing the blood to clot in a centrifuge tube, freeing the coagulum with wooden applicators, and centrifuging to separate the serum from the clot. The clear serum was transferred to screw-capped vials which were sealed with adhesive tape. The vials were placed in wooden blocks, packed in boxes, and shipped to the University of Illinois by the established courier system. At the University the specimens were checked in and then stored at -25°F or in a refrigerator until chemical analysis was performed.

5. Other Excreta

Paraffin-lined cartons were kept at designated areas for use in case of vomiting, which occurred infrequently. The specimens of vomitus were labelled with subject's code number and date. After delivery to the University specimens were pooled according to appropriate 24-hour periods, diluted to 500 ml, and aliquoted. The aliquots were stored at -25°F until chemical analysis was performed.

No attempt was made to collect sweat. Since the investigation was conducted during a cold season, it was assumed that only small amounts of sweat would be lost and then only by the men engaged in hard work while at Camp McCoy. For purposes of calculating balances it was assumed that the subjects of Flights 1 and 2 lost 500 ml of sweat per day during the two experimental weeks.

F. NUTRIENT AND OTHER BALANCES

1. Caloric Balance

Intake. Calculations of the caloric intake were based entirely on data derived from standard tables of the proximate composition of the ration components and other foods fed the subjects of the investigation.

Output. The caloric expenditure was calculated in a different manner than that employed in the report of the temperate study of 1953. In the winter trials the flight leaders maintained a daily log of the activities of their separate charges. Since all members of the flight, on the average, engaged in comparable activities, it was assumed that the mean times used by the flight as a whole for sleeping, resting, marching, briefing, etc. could serve as a basis for estimating the mean daily caloric output by the subjects. Accordingly, the daily activities were separated into three categories: resting, light activity, and marching (Table II. 19).

TABLE II. 19

CATEGORIES OF DAILY ACTIVITY

Resting	Light Activity	Marching
Sleeping. Resting during tests.	Sitting (e.g., meals, classroom, movies). Policing living facilities (barracks, camp sites, etc.). Survival instruction and practice. Reading, writing letters. Washing clothes. Gathering firewood.	Prescribed marching to and from mess hall and classroom. Half-mile run.

The times engaged in sleeping and resting and in marching were known from the daily schedules and the flight leaders' logs. The mean hours per day in

each of the six weeks was calculated for these two categories. The remaining hours of the 24 were assumed to have been devoted to light activity. The next problem was to assign a reasonable but arbitrary caloric value to each of the three categories. The following were selected (Sherman, 1941):

1.	Resting:	1.1 Cal/kg/hr
2.	Light activity:	2.2 Cal/kg/hr
3.	Marching	4.0 Cal/kg/hr

In the pre-periods the caloric expenditure for each subject was calculated from the formula

> Caloric Output = (Mean Body Wt in PI or PII) x [(Hr of Resting) x (1.1 Cal/kg/hr) + (Hr of Light Activity) x (2.2 Cal/kg/hr) + (Hr of marching) x (4.0 Cal/kg/hr)].

In the recovery periods the only change in the above formula was to use the weight of the mid-day of REC I and REC II instead of the mean weight. This was done since the body weight was increasing as recovery progressed.

In the experimental periods a different formula was adopted. Allowance had to be made for the extra clothing the subjects wore when engaged in light activity and marching. Approximately 10 kg (Table II. 9) was worn for protection against the cold. The formula used for calculating the caloric expenditures under these circumstances was

> Caloric Output = (Body Wt at Mid-Day of EXP I or EXP II) x (Hr of Resting) x (1.1 Cal/kg/hr) + (Body Wt at Mid-Day of EXP I or EXP II plus 10) x [(Hr of Light Activity) x (2.2 Cal/kg/hr) + (Hr of Marching) x (4.0 Cal/kg/hr)].

Balance. The caloric balances derived from the present investigations are admittedly only estimates. However, the results (Section III) are reasonable and considered to represent the approximate levels of caloric deprivation experienced during the six weeks of study. The caloric balance was calculated in the same fashion as described for the 1953 study.

2. Water Balance

In computating the water balance, the following general equation holds:

> Water Balance = Water Gain (all sources) - Water Loss (all sources).

Water gain is calculated from several factors, some of which can be measured directly and others of which can be calculated. The factors which are measured directly are: fluid water consumed, water preformed in food, and water derived from oxidation of nutrients in the ration (i.e., metabolic water). The factor which must be calculated is the water derived from oxidation or breakdown of tissue in the body itself. This calculation is based on many questionable assumptions.

Water loss is also calculated from several factors, some being measured directly and others calculated. The factors measured directly are urine output and loss of water in feces and blood. The important variables which were impossible to measure under field conditions in the present study are insensible water loss (i.e., water evaporated from lungs and from skin) and sweating.

Water Gain. The total daily gain in body water was calculated as described in WADC TR 53-484.

Water Loss. The urinary volume and the volume of vomitus were measured. The water loss resulting from venipuncture was calculated by assuming that 80% of the volume of blood drawn was water. The rate of insensible water loss was calculated. A mean value of 15.8 ml/kg/day was derived from the resting data on insensible water loss measured by Sargent et al. (1954). This value was multiplied by the subject's mean body weight for the pre-period and the calculated value was assigned to each of the six weeks. It was assumed that only men engaged in hard work sweated. Accordingly, a value of 500 ml/day was included among the water losses of EXP I and EXP II for Flights 1 and 2. The wet fecal weight was measured. The water content was calculated by assuming that 50% of the wet weight of "normal stools" and 75% of the wet weight of "diarrheal stools" was water.

Water Balance. For the purposes of this experiment then a virtual balance was calculated. Because of the questionable assumptions which are made in computing water from tissue breakdown (so-called metabolic mixture), such calculations were not made. Under the conditions of the present investigation it was impossible to measure sweat loss and so a value for hard working men was assumed. The virtual water balances presented in this report were computed according to the equation:

"Virtual Water Balance" = (Fluid intake + (Water Preformed in Food) + (Water Derived from Oxidation of Nutrients) - (Urine Loss) - (Insensible Water Loss) - (Blood Plus Fecal Water Loss).

Interpretation of this water balance must be made with two reservations. First, if sweat loss were greater than assumed, the true balance might be lower than the virtual. Second, if tissue breakdown were large, the true balance might be higher than the virtual.

3. Nitrogen Balance

Computation of the nitrogen balance involved use of data from chemical analysis of the specimens collected and of data cited in the literature. The balances were virtual to the extent that no measurement was made of nitrogen lost in sweat.

Nitrogen Gain. The only source of nitrogen gain was the food eaten. The protein content of the ingested foods was calculated from the tables discussed above. (See section on Dietetic Methods.) Where such data were not available, the ration components were analyzed directly. The protein was converted to

nitrogen-equivalent by use of the factor 6.25:

$$\text{gm Nitrogen} = \frac{\text{gm Protein}}{6.25}$$

Nitrogen Loss. Nitrogen was lost from the body as (1) urinary nitrogen, (2) fecal nitrogen, (3) whole blood nitrogen, and (4) nitrogen in vomitus, sweat, hair, nails, and desquamated epithelium. Urinary and fecal nitrogen were measured on the six and seven-day pooled specimens of urine and feces, the results being expressed as gm N/day. The nitrogen lost in blood withdrawn was calculated by assuming that the total nitrogen in the blood withdrawn once a week was 3.0 gm/100 ml (Hawk, Oser, and Summerson, 1951). Since the vomitus was negligible, it was not analyzed. No sweat was collected and no values were assumed. The combined loss of nitrogen from hair, nails, and skin was assumed to be 0.2 gm/day (Taylor, 1911; Lusk, 1928).

Nitrogen Balance. The nitrogen balance was computed according to the formula:

> Nitrogen Balance (gm/day) = (Nitrogen Intake from Food, gm/day) - (Nitrogen Lost in Urine, Feces, Blood, Skin, Hair, and Nails, gm/day).

It will be noted that the nitrogen contributed to the intake by catabolism of tissue was not considered. Since the assumptions involved in making these calculations are not acceptable, no such computations are presented.

4. Fat Absorption

Fat absorption was computed by deducting from the calculated average daily intake of fat in food the total fecal fat, which was measured in each seven-day pooled fecal specimen. Where the intake of fat was zero, no calculation was made. To our knowledge, a negative absorption has no meaning. There is no information that fat is excreted into the gastrointestinal tract.

5. Mineral Balance

The balances were calculated for sodium, potassium, and chloride. The general form of the equations were the same as that which have previously been discussed. Because of the lack of data on sweat loss, the balances computed were virtual.

Mineral Intake. Where information on the mineral content of food was not available, the ration components, special food, etc., were analyzed directly by standard chemical procedures. Local tap water was used for drinking and cooking. This water contained appreciable concentrations of minerals (Table II. 17). The minerals contributed by the liquid intake were added to the minerals consumed in the food per se.

Loss of Minerals. The pooled specimens of urine and feces were analyzed for sodium (urine only) potassium, and chloride (urine only). The fecal loss

of sodium and chloride was assumed to be negligible (Clark, 1926). This assumption was justified by the fact that the fecal Na averaged less than 1.0 mEq/day for eight healthy young men (Sargent et al., 1954). It was also assumed that the loss of these minerals due to venipuncture was negligible in relation to the magnitude of the fecal and urine loss. Because there was relatively little vomiting, this material was not analyzed. Since no sweat was collected, there were no analyses on perspiration. However, it was assumed that during the experimental weeks the subjects in Flights 1 and 2 lost 25 mEq/day of NaCl.

Mineral Balance. The mineral balance was calculated from the formula

Mineral Balance (Na, K, Cl) = Mineral Intake (Na, K, Cl) - Urinary Loss (Na, K, Cl) - Fecal Loss (K) - Sweat Loss (Na, Cl).

The balances were expressed in mEq/day.

No attempt was made to compute, on the basis of dubious assumptions, the minerals contributed to the intake by catabolism of tissues.

6. Vitamin Balance

No measurement was made of the vitamin balance. As previously stated, the subjects were given luxus supplies of these nutrients. It was assumed that, at all times, the subjects were in positive vitamin balance, and that vitamin deficiencies in no way contributed to the functional alterations produced by the several nutrient mixtures studied.

7. Acid-Base Balance

An elaborate study of acid-base balance was not made. It was felt that useful information could be obtained on gross and significant changes in acid-base balance merely by measuring urinary titrable acidity and quantitative pH. Such information was supplemented by quantitative measurement of urinary ammonia and qualitative analysis for ketonuria.

G. CLINICAL PATHOLOGY

1. Hematology

The hematological determinations were made by standard procedures of clinical pathology. The blood used in these analyses was venous blood collected by venipuncture with stasis. The subjects were not postabsorptive. The first few drops of blood from the needle were placed on glass slides and smears were prepared for staining. The remainder of the blood was placed in a screw-capped vial containing a standard amount of dried double oxalate (sodium and ammonium oxalate, prepared according to the formula of Hepler, 1949). The hematological measurements were all completed in the field within a few hours after the samples were obtained. The following analyses were made according to procedures described in WADC TR 53-484: (1) white blood cell count, (2) differential leukocyte count, (3) erythrocyte sedimentation rate

and hematocrit.

2. Blood Chemistry

Venous blood collected with stasis was used for all chemical analyses. For glucose the blood was delivered into screw-capped vials containing dried double oxalate. For all other analyses, the serum was collected after centrifuging clotted blood. The serum was transferred to screw-capped vials which were shipped to the University by the courier system described earlier in this report. The vials were stored as described above in the section dealing with specimens. The subjects were not postabsorptive when blood for chemical analysis was drawn.

The following analyses of serum were conducted according to procedures detailed in WADC TR 53-484: calcium, sodium, potassium, chloride, amylase, cholinesterase, and freezing-point depression.

Whole Blood Glucose. The determination of blood glucose was modified considerably from that used in the temperate study of 1953. The modifications were introduced specifically to make the determination suitable for use in the field. Since a combination of available methods was utilized, the details are given in Appendix I. In brief, a tungstic acid filtrate was prepared. To an aliquot of the filtrate were added alkaline copper tartrate before boiling and acid phosphomolybdate solution after boiling. After color development, the optical density was measured at 650 mμ in a Coleman Jr. Model 6 Spectrophotometer. Deproteinization was conducted in a Lusteroid tube; reduction and color development were carried out in standard 18x150 mm Pyrex test tubes, previously optically matched. Three standard solutions controlled each series of analyses. The method was fully validated prior to use and consistently yielded 100% recoveries.

Serum Alkaline Phosphatase and Inorganic Phosphate (Consolazio, Marek and Johnson, 1951). In the determination of alkaline phosphatase, the amount of inorganic phosphate released from β-glycerophosphate by the enzyme is used as a measure of the serum concentration of the phosphatase. The initial concentration of inorganic phosphate was our measure of that substance; the increment in inorganic phosphate, the measure of the enzyme.

Serum Creatinine. A review of the recent literature (Mandel and Jones, 1953) on the methods for measuring serum creatinine indicated that the most reliable data could be obtained by methods employing Lloyd's reagent to separate true creatinine from pseudocreatinine. The method of Haugen and Blegen (1953) was adopted. In this method a 1:10 tungstic acid filtrate of serum is prepared in the same fashion as in the method of Peters (1942) employed in the test of 1953. The creatinine is absorbed on to Lloyd's reagent and then eluted into alkaline picrate. Comparative studies between the methods of Peters (1942) and Haugen and Blegen (1953) are summarized in Table II. 20. The values for creatinine in a method employing Lloyd's reagent are consistently lower than the values in a method which does not employ Lloyd's reagent. By definition the difference is pseudocreatinine. In our hands, the concentration of pseudocreatinine in eight non-fasting sera

TABLE II. 20

TOTAL CHROMOGEN, "TRUE" CREATININE, AND PSEUDOCREATININE IN SERA FROM NON-FASTING SUBJECTS

Serum No.	Creatinine, mg/100 ml		
	Peters	Haugen and Blegen	Pseudo-creatinine*
1	1.00	0.78	0.22
2	1.14	0.90	0.24
3	0.91	0.85	0.06
4	0.97	0.45	0.42
5	1.08	0.65	0.43
6	1.35	1.00	0.35
7	1.38	1.19	0.19
8	1.38	1.03	0.35

*Pseudocreatinine determined by difference between values in column 2 and column 3.

TABLE II. 21

RECOVERY OF CREATININE ADDED TO SERUM

Creatinine Added	No. of Tests	Per Cent Recovery*	
		Peters	Haugen and Blegen
1.00 mg/100 ml	5	86.4±3.9	92.0±3.7
2.00 mg/100 ml	5	88.4±4.5	90.4±6.9

*Difference between recoveries at 1.00 mg/100 ml by two methods is significant by "t" test at 2% level; other differences not significant at 5% level.

from two healthy females and three healthy males ranged from 0.06 to 0.43 mg/100 ml. Comparable data are reported by Haugen and Blegen. Recovery of added creatinine is good by either method (Table II. 21) and the values agree with those reported by Mandel and Jones (1953).

Serum Non-Protein Nitrogen (Consolazio, Marek, and Johnson, 1951). This determination replaced serum urea nitrogen. The change was dictated by the simpler procedures in the former measurement.

Serum Total Cholesterol. A modification of the method of Feichtmeir and Bergerman's (1953) anthrone procedure was employed. According to our experience during the present study, this method cannot be recommended as a procedure when large numbers of samples must be analyzed. Serum cholesterol esters were not measured. These substances deteriorate on standing even when the serum is frozen and erroneous values may be obtained. It was not possible to complete analyses for esters within the three-day limit set by our validation studies.

3. Urine Chemistry

The following measurements were made on the pooled specimens: total

nitrogen, calcium, phosphate, sodium, potassium, chloride, and 17-ketosteroids.

The following measurements were made on the two-hour urinary specimens: freezing-point depression, creatinine, creatine, ammonia, pH (electrometric), and titrable acidity.

Special Urinary Specimens. An aliquot of undiluted urine was taken from the 24-hour specimens collected on the day prior to, the day of, and the day after the administration of heavy water (deuterium oxide). These aliquots were analyzed for deuterium oxide by a "falling drop method" described in detail in Appendix I. Urinary specimens obtained at this time from flight leaders were also analyzed for 17-ketosteroids.

Aliquots of the diluted daily urine specimens were saved for each subject from Day 13 of the pre-period through Day 2 of the recovery period. These specimens to date have been analyzed for 17-ketosteroids and total osmolar content with the Fiske Osmometer (Fiske Associates, 1954).

4. Urinalysis

Qualitative tests were made on both the two-hour urinary and the diluted daily urinary specimens (Day 13 of pre-period through Day 2 of recovery) according to procedures previously described in WADC TR 53-484: albumin, glucose, and ketone bodies. The sediment of the two-hour urine was studied quantitatively by a modification of the method of Addis.

5. Analysis of Feces

The qualitative and quantitative procedures detailed in WADC TR 53-484 were followed: fecal fibers, occult blood, total nitrogen, calcium, phosphorus, potassium, and total fecal fat. Fecal sodium and chloride were not measured for they are present in negligible amounts (vide supra).

6. Liver Function

The battery of liver function tests was somewhat different than that used in the temperate study of 1953. The measurements used to appraise liver function were: serum cholinesterase, serum total cholesterol, fasting blood sugar, serum alkaline phosphatase, color of feces, and clinical examination. The rationale for these tests has been discussed in WADC TR 53-484.

7. Renal Function

The kidney function was appraised by means of urinary volume, creatinine clearance, osmotic clearance, urine/serum osmotic ratio (U/S ratio), serum non-protein nitrogen, serum creatinine, and modified Addis count. The procedures used, the calculations made, and the rationale for these functional tests have been discussed previously in WADC TR 53-484.

Additional study of the data collected in 1953 and subsequent studies on the influence of protein intake on creatinine clearance dictated some modifi-

cation in the handling of subjects prior to performing kidney function tests on them. The background for the modifications was a review of the 1953 data and a study performed on two volunteer graduate students.

Two-Hour vs. 24-Hour Creatinine Clearance. A protocol for conducting renal function tests depends upon careful control of the several variables which might prejudice the results. The most significant variable influencing the results is the dietary intake of protein. According to Camara et al. (1951), if the protein intake is less than 40 gm/day excellent data can be obtained from non-fasting subjects. When the diet provides more than 40 gm/day of protein, the subject should be on a low protein diet for 48 hours prior to conducting the creatinine clearance test. This ideal arrangement would be impossible to realize under the conditions of the field trials, for the dietary intake of protein will be fixed at levels greater than 40 gm/day in many of the subjects.

The data of 1953 were collected with a view to providing a solution to this problem. Once a week each man was given a two-hour test in which a timed urinary specimen was collected and a blood sample was drawn. The subjects were not fasting. The blood and urine were analyzed for creatinine. On the same day a twenty-four hour urinary specimen was collected and this urine was also analyzed for creatinine. The minute volume of serum cleared of creatinine was calculated from the relation C (ml/min) = U (mg/ml) x V (ml/min) / S (mg/ml), where C is the clearance, U, urinary creatinine, V, minute urinary volume, and S, serum creatinine. An analysis of the data is given in Table II. 22. Three experimental conditions were given special attention. (1) When all the

TABLE II. 22

CORRELATION BETWEEN TWO-HOUR AND 24-HOUR CREATININE CLEARANCES

Experimental Conditions	N	Regression Equations*	r
(1) All data	146	$Y' = 49.5201 + 0.6528\ X$	0.621
(2) Protein intake < 40 gm/day	39	$Y' = 7.6087 + 0.9180\ X$	0.824
(3) Fasting - thirsting, 72 hr	22	$Y' = 1.4159 + 0.9733\ X$	0.920

* Y' = Clearance from two-hour urine; X = Clearance from 24-hour urine.

data were treated regardless of the experimental conditions, the correlation coefficient (r) was 0.621. Study of a scatter-diagram of these 146 points revealed that in 14 instances, the correlation between the two clearances was poor. Nine points were accounted for by two subjects and 13 of the points fell in the pre-period or recovery period when the protein intake was high. In general, the two-hour test, in these instances was twice as high as the 24-hour test. Postcibal changes in serum or urinary creatinine caused by the high intake of protein may have caused these poor correlations. (2) When only data collected at a time when the subjects were on diets providing less than 40 gm of protein per day were used, the correlation coefficient rose to 0.824. The intercept of the regression equation was close to zero (X = 0, Y' = 7.6).

(3) An even better correlation was achieved in a special 72-hour fasting - thirsting experiment on two alternate subjects. The coefficient of correlation was 0.920 and the intercept was hardly different from zero (X = 0, Y' = 1.4). Thus, when the protein intake is less than 40 gm/day., the two-hour test will yield reliable clearance values on the non-fasting subject.

Validation of proposed field two-hour test: In the field test, it was planned that the 88 subjects would be subjected to the two-hour test in groups of 22 mean each: 0700-0900, 0900-1100, 1300-1500, and 1500-1700. Following this scheme all the subjects were handled in one day. Furthermore, it was planned to test the two morning groups without breakfast and the two afternoon groups with breakfast but without lunch so that the men could be somewhat postabsorptive. The problem to be solved was: when should the subjects subsisting on more than 40 gm/day of protein be tested in order to obtain the most consistent data? Using the crossover technic, the following experiment was conducted.

Day 1 (Mon. 7 Dec.):	Void at 0700 and discard the specimen; begin 24-hour collection; eat 1/3 of calories at each of three meals: J.W., protein diet at 3000 Cal/day; S.M., non-protein diet at 2000 Cal/day. (See Table II. 23).
Day 2 (Tues. 8 Dec.):	End 24-hour urine at 0700 and begin new 24-hour collection; repeat feedings as on Day 1.
Day 3 (Wed. 9 Dec.):	End 24-hour urine at 0700; no breakfast; drink 100 ml of H_2O; venipuncture at 0745 on S.M. and 0800 on J.W.; void into special bottles at 0900; drink 100 ml of H_2O; venipuncture at 1000; void into special bottles at 1100; 50% of calories at lunch and supper; remainder of urine in 24-hour bottle.
Day 4 (Thurs. 10 Dec.):	End 24-hour urine at 0700 and begin new 24-hour bottle; 50% of calories at breakfast; no lunch, void into 24-hour bottle at 1300 and drink 100 ml of water; venipuncture at 1400; void into special bottle at 1500 and drink 100 ml of H_2O; venipuncture at 1600; void into special bottle at 1700; 50% of calories at supper; remainder of urine in 24-hour bottle.
Day 5 (Fri. 11 Dec.):	End 24-hour urine and begin new specimen bottle; eat 1/3 of calories at each of three meals: S.M., protein diet at 3000 Cal/day; J.W., non-protein diet at 2000 Cal/day.
Day 6 (Sat. 12 Dec.):	End 24-hour urine and begin new specimen bottle; repeat feedings as on Day 5.
Day 7 (Sun. 13 Dec.):	End 24-hour urine and begin new collection period; two-hour tests, venipuncture, and feedings according to plan for Day 4.
Day 8 (Mon. 14 Dec.):	End 24-hour urine and begin new collection

period; two-hour tests; venipuncture, and feeding according to plan for Day 3.

Tues. 15 Dec.: End 24-hour collection at 1700.

TABLE II. 23

DIETS USED IN CLEARANCE EXPERIMENT

Diet	Cal.	Prot., gm	CHO, gm	Fat, gm
Protein (1)	3131	123	400	123
% calories	100	16	51	34
Non-Protein (2)	2056	0	514	0
% calories	100	0	100	0

(1) Components: meat bar, crackers, jam, raisins, sugar, soluble milk, and catsup.

(2) Components: spice drops and sugar.

The data collected during this experiment have been summarized in Tables II. 24 and II. 25. Several significant observations stand out. (1) The serum

TABLE II. 24

CREATININE CLEARANCE CALCULATED FROM TWO-HOUR TEST

Subject and Time of Test	Non-Protein Diet			Protein Diet		
	Serum Creat. mg/100 ml	Urine Creat. mg/min	Clearance ml/min	Serum Creat. mg/100 ml	Urine Creat. mg/min	Clearance ml/min
S.M.						
0700-0900	1.20	1.54	122	1.20	1.53	127
0900-1100	1.20	1.47	122	1.15	2.00	174
1300-1500	1.20	1.47	122	1.48	2.00	135
1500-1700	1.20	1.53	127	1.48	2.08	140
J.W.						
0700-0900	0.76	1.23	162	0.82	1.05	128
0900-1100	0.74	1.60	218	0.82	1.57	191
1300-1500	0.82	1.42	173	1.14	1.75	153
1500-1700	0.72	1.46	203	0.88	1.50	170

creatinine, the minute output of creatinine, and the creatinine clearance were more constant from test to test when the subjects were on the non-protein diet than when they were on the protein diet. (2) While on the protein regimen, the morning serum creatinine values (no breakfast) were similar to those obtained during the non-protein regimen. The afternoon values (no lunch but 50% of calories at breakfast) were higher than the morning values. (3) The afternoon minute outputs of creatinine were more consistent than the morning values when the subjects were on the protein diet. (4) Likewise, the clearances were more constant. (5) The afternoon minute outputs of creatinine agreed more closely with minute outputs calculated from the 24-hour urine than did the morning outputs when the subjects were on the protein diet. (6) While on the non-protein diets the agreement between the minute output of creatinine in the two-hour urine and the 24-hour urine was equally good at

TABLE II. 25

COMPARISON BETWEEN CREATININE CLEARANCE CALCULATED FROM 24-HOUR AND 2-HOUR TESTS

Subject and Diet	Day	24-Hour Period: Mean Serum Creat. mg/100 ml	24-Hour Period: Urine Creat. mg/min	24-Hour Period: Clearance ml/min	Predicted Clearance*	Clearances from Table II. 24: 0700-0900	0900-1100	1300-1500	1500-1700
S.M.									
Non-	1	----	1.46	---	---	---	---	---	---
Protein	2	----	1.44	---	---	---	---	---	---
	3	1.20	1.62	135	132	122	122	---	---
	4	1.20	1.42	119	116	---	---	122	127
J.W.									
Non-	5	----	1.24	---	---	---	---	---	---
Protein	6	----	1.31	---	---	---	---	---	---
	7	0.77	1.33	173	166	---	---	173	203
	8	0.75	1.45	193	185	162	218	---	---
S.M.									
Protein	5	----	1.64	---	---	---	---	---	---
	6	----	1.52	---	---	---	---	---	---
	7	1.48	1.89	128	125	---	---	135	140
	8	1.18	1.67	142	138	127	174	---	---
J.W.									
Protein	1	----	1.99	---	---	---	---	---	---
	2	----	1.78	---	---	---	---	---	---
	3	0.82	1.80	220	210	128	191	---	---
	4	1.03	1.79	174	167	---	---	153	170

*Predicted from regression equation (2), Table II. 22.

each of the four diurnal periods. (7) Using the mean serum creatinine to calculate the clearance from the 24-hour urinary output of creatinine and the regression equation in Table II. 25 to calculate the predicted value for the two-hour clearance, it was found that, when on the protein diet, the afternoon clearance values agreed more closely with the predicted values than did the morning values. (8) In summary, then, it would appear that more reliable creatinine clearances would be obtained on subjects subsisting on more than 40 gm/day of protein if the subjects were fed 50% of the caloric allowance for breakfast and none at lunch and tested in the afternoon rather than giving them no breakfast and testing them in the morning. On the basis of this experiment, the two-hour test used during the winter trials was set up. The protocol for the test will be given in a subsequent section.

8. Endocrine Functions

The measurement of the functional changes of the endocrine glands is an integral part of the methodological armamentarium of an investigation of stress. Two general types of procedure are available. (1) A fragment or metabolite of an original hormone or the hormone itself may be measured in a biological fluid, such as blood, urine, or feces. The method may be either

chemical or biological (bioassay). (2) A process or function known to be, at least in part, regulated by the activity of an endocrine may be quantitated so that inferences may be drawn regarding the functional activity of the endocrine gland. Both types of approaches were employed in this investigation, and in general they did not differ from those described previously in WADC TR 53-484.

The following measurements and analyses were made to serve as a basis for deducing functional changes in the endocrine glands: total urinary 17-ketosteroids, serum sodium, potassium, calcium, inorganic phosphate, cholesterol, alkaline phosphatase, and amylase, blood glucose, resting metabolic rate, differential leukocyte count for neutrophils, lymphocytes, and eosinophils, water tolerance test, and urinary creatine.

The methods of analysis have been discussed elsewhere in this report. Two changes were made from the 1953 study. Serum lipase was not measured, for no significant alterations were observed during the course of the study of eight volunteer students. Serum alkaline phosphatase was measured, for in the 1953 study certain nutrient combinations, notably 2/20/78, produced suggestive changes in serum calcium and inorganic phosphate. The observations were consistent with functional hypoparathyroidism. In the event that the winter trials might confirm these observations, it was decided to add measurement of serum alkaline phosphatase, for the level of this enzyme in the serum is, in part, related to the status of the parathyroid glands (Bodansky and Bodansky, 1952).

H. RESPIRATORY FUNCTION AND RESTING METABOLISM

It must be emphasized at the outset that the respiratory measurements in this year's study were by no means as complete or as accurate as the investigators had hoped. Nevertheless, considerable information was obtained, especially on pulmonary ventilation. As described in detail in Section II N, resting metabolism was incorporated in one of the "combined tests". Each subject was measured once a week, each at the same time of day on each occasion.

The theoretical justification for measuring resting metabolism instead of the more conventional basal metabolic rate was discussed in a previous report (Sargent et al., 1954). Perhaps a restatement at this time would not be out of place.

Since the observations were made that a lowering of the basal metabolic rate (B.M.R.) occurs with reduced caloric intake, much work has been done to determine whether this decrease is a physiological adaptation. Keys et al. (1950) state "of all possible metabolic adaptation mechanisms, a decrease in the B.M.R. would be the most important in its over-all significance."

The purpose of this research was, in part, to determine whether the resting metabolic rate (R.M.R.) was affected in a comparable manner as the B.M.R. by caloric intake. In addition to studying the effect of caloric intake on the R.M.R., the effects of water limitation and distribution of the calories in the nutrient mixture were also investigated.

In this study the R.M.R. refers to the metabolism determined on a reclining subject after a half hour's rest in a comfortable room, at least one hour following food ingestion with activity being limited to mild exercise prior to the determination. Although the B.M.R. constitutes a more stable measurement in that it cannot voluntarily be changed, the use of the R.M.R. can be justified for the following reasons: (1) The subjects need not be postabsorptive. (2) The determination can be made at any time during the day without great inconvenience to the subject. (3) It is more representative of the daily metabolic expenditure. As a result of these advantages, an interruption in their dietary regimen does not occur, more subjects can be studied, and determinations can be made without interfering with other desired observations on the subjects.

The method chosen was a new open-circuit method, devised during work under a contract with the U. S. Army Quartermaster Research and Development Command (Johnson, Nielsen, Evans and Benedix, 1954). Details of the development, validation, and limitations of the three-gasmeter method are to be found in the report of those investigators.

The observations, under the general supervision of Dr. W. S. Boyd, were made for the most part by Dr. R. F. Kline; 1/Lt. C. Ortiz, Capt. J. Schroering and Mr. R. D. Evans. Detailed instructions as given to all observers are incorporated in Appendix I of the present report, together with the forms used for the collection of data. The apparatus and its use are shown in Figures II. 32 and 33. In brief, the method consists of measuring the inspired air by means of dry gasmeter I, the expired air by means of dry gasmeter II, and the expired air following removal of carbon dioxide by dry gasmeter III. The oxygen consumption was determined by means of the STP difference between meters I and III, and the carbon dioxide, by the STP difference between meters II and III. These differences were then multiplied by an experimentally determined factor. The pulmonary ventilation was determined by multiplication of the STP meter reading II by an experimentally determined factor. The equations applicable to the two machines used were as follows:

Unit 1

Pulmonary ventilation = (STP meter reading II) x 1.08
Oxygen consumption = (STP meter I-STP meter III) x 0.95
Carbon dioxide production = (STP meter II-STP meter III) x 1.25

Unit 2

Pulmonary ventilation = (STP meter II) x 1.09
Oxygen consumption = (STP meter I-STP meter III) x 0.99
Carbon dioxide production = (STP meter II-STP meter III) x 1.22

Surface area was computed from the DuBois-Meek formula by means of a nomogram (Consolazio, Johnson, and Marek, 1951). The data from which the DuBois-Meek formula was derived were obtained from normally hydrated individuals, and because of this fact, in the present study a correction was made for dehydration when it was known to exist. The correction was made by adding to the measured body weight, an amount equivalent to the weight of water lost during dehydration. This latter figure was obtained from measurement of deuterium oxide space in all subjects.

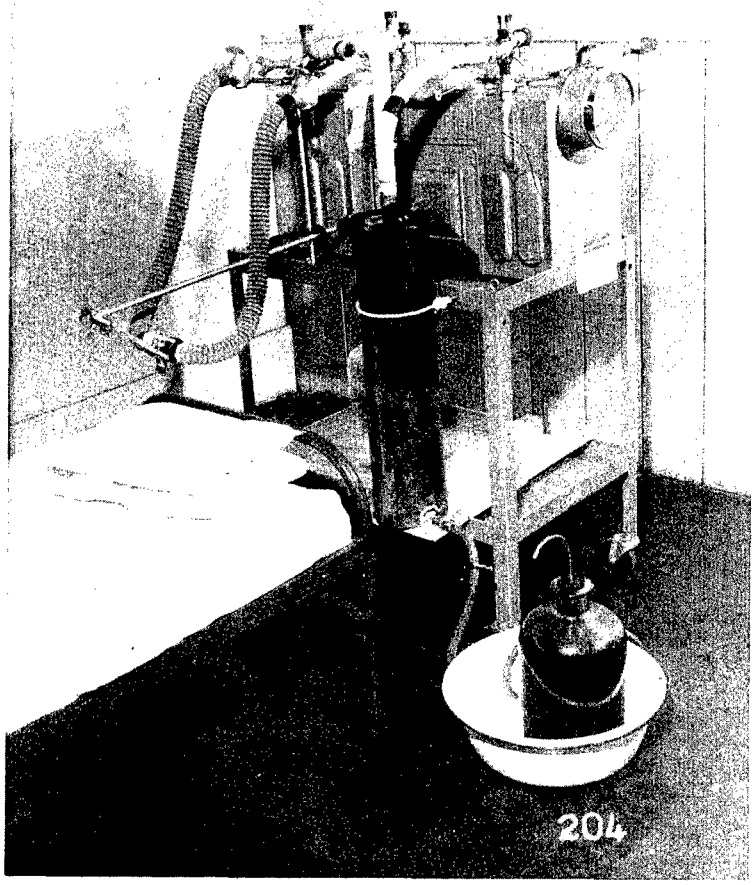


FIGURE II. 32. RESPIRATORY METABOLIC APPARATUS.

As stated above, the method did not prove entirely satisfactory in the present field tests. In preliminary trials, the method had seemed satisfactory; however, in the pressure of the schedule, undetected technical errors crept in. Specifically, the machines week by week developed a slow failure in absorbing carbon dioxide. Not until the data were scrutinized statistically did this failure become apparent. Thus, although the method shows great promise, the data must be viewed with reservations. Pulmonary ventilation is accurate; oxygen consumption and carbon dioxide production may not be.

I. CARDIOVASCULAR FUNCTION

The following cardiovascular tests were made: systolic and diastolic blood pressure, pulse rate, and electrocardiogram. All of these measurements were taken during the two-hour test with the subject at rest.

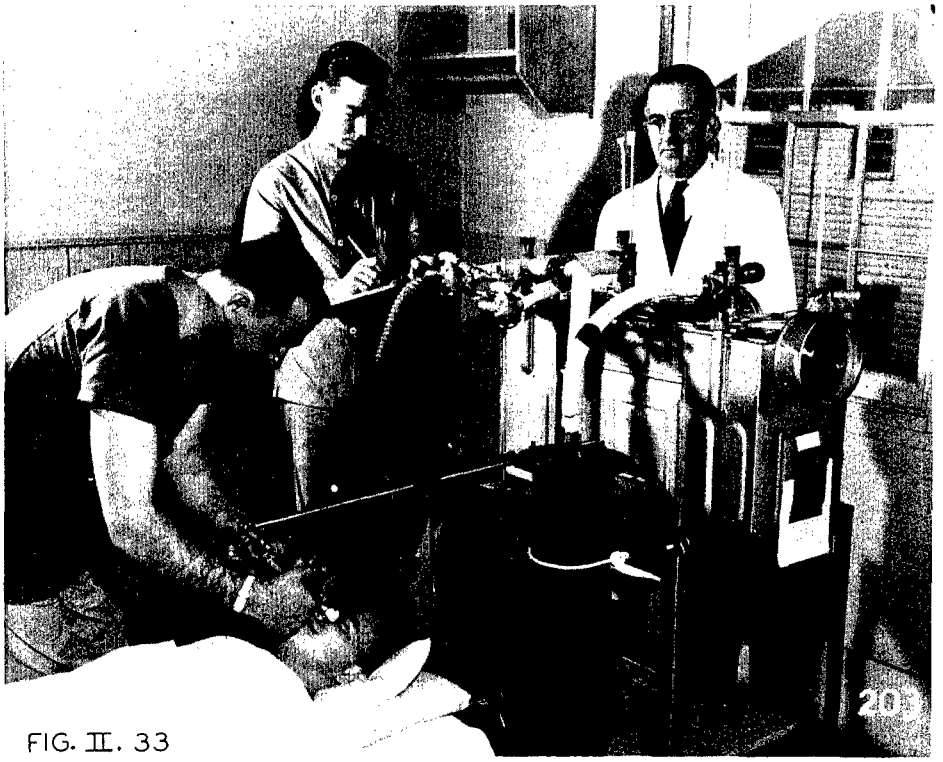


FIG. II. 33

FIGURE II. 33. RESPIRATORY METABOLIC APPARATUS IN USE. SUBJECT: S/SGT. BRUNGARD. OBSERVERS: LEFT TO RIGHT: M/SGT. BILICH, S/SGT. KELSEY, AND DR. R. KLINE.

J. CENTRAL NERVOUS SYSTEM

Only a limited battery of tests was conducted to appraise the function of the central nervous system. No psychomotor measurements were made. The only psychological procedure was the measurement of the subjects' judgement of the passage of time (Sargent et al., 1954). This measurement was made in the rest period prior to determining the metabolic rate as will be described in a subsequent section. The electroencephalogram was also recorded in this resting period.

K. BODY COMPOSITION

Two techniques are available for study changes in body composition: (1)

direct measurement and (2) calculations from nomograms and empirical formulae. The latter are no more valid than the assumptions made in setting up the empirical formulae. The applicability of these assumptions to metabolic investigation is limited, for frequently the empirical conditions are not similar. The lack of fully validated broadly applicable procedures for studying changes in body composition is one of the most serious deficiencies of metabolic research generally. In so far as the present report is concerned, little use will be made of these empirical formulae.

1. Body Weight

The body weight of each subject was measured daily after passing the first morning urine and before eating breakfast. They were weighed by members of the technical staff or the flight leaders. The subjects, clothed only in shorts and "T" shirt (Figure II. 34), were weighed on a scale sensitive to the nearest ounce. The daily weights were converted to the nearest 0.1 kg by dividing the weight in pounds by 2.2.

2. Body Water (Deuterium Oxide Space)

The importance of water in biological systems is common knowledge. Excesses of water are dealt with at all levels of life providing that physiological mechanisms are normally functioning; lack of sufficient water, on the other hand, is not compatable with life and no man can survive under this condition. It was our purpose to determine whether or not it was possible to assess an individual's state of hydration by the manner in which he handled a water load. To achieve this end we determined the total body water in men under conditions of normal hydration and chronic dehydration; concurrently with the body water determinations we administered a water load and followed its effect, as evidenced by degree of diuresis, on these men.

The Dilution of Deuterium Oxide as a Measure of Total Body Water. Deuterium oxide was introduced in 1934 by Hevesy and Hofer (1934) for the estimation of total body water by the dilution technique. The toxicity of heavy water was demonstrated by Lewis (1934) shortly after its discovery by Urey. In the amounts used for body water determinations, Schloerb et al. (1950) state that any toxic effects that may be produced by the incorporation of deuteriated water within the total body water of an organism are of minor importance. Deuterium, the stable isotope of hydrogen, and tritium, the radioactive isotope of hydrogen, both have been shown to exchange with the hydrogen of organic compounds within the body (Pinson, 1952). The fact that the hydrogen of deuterium oxide and tritium oxide exchanges for the hydrogen of organic compounds within tissue is the primary disadvantage of using these solutes for total body water determinations. It is of great interest to note that the exchange of tritium with the labile hydrogen of fat is small or undetectable (Prentice et al., 1952), but large in muscle, gut, liver, kidney, and plasma solids, in that order. Prentice et al. (1952) suggest that this exchange error is of the order of two to four percent of the total body water. It is generally accepted that the same type of error shown to occur with tritium oxide determinations of total body water are also characteristic of deuterium body water determinations. Since the exchange error will vary with

FIG. II. 34

FIGURE II. 34. WEIGHING SUBJECTS, CAMP McCOY, WISCONSIN, WINTER, 1954. SUBJECTS: LEFT TO RIGHT A/3C NUQUI, A/3C GILDERSLEEVE AND A/3C PAYTON. OBSERVERS: LEFT TO RIGHT A/1C JACKSON, M/SGT. BILICH, AND CAPT. F. SARGENT, II.

the proportion of lean body mass and fat present, a constant correction factor cannot be used to eliminate this error.

After the equilibration of deuterium oxide with the water of the body, deuterium is eliminated in an amount that can be determined. There is some question in our minds that the rate of decay from the body is a smooth exponential function as suggested by Schloerb et al. (1950). We have evidence to suggest that the rate and amount of deuterium eliminated are both dependent upon the state of water balance. Although in deuterium oxide dilution studies neither the insensible loss nor the sweat loss of deuterium oxide has ever been accounted for (Pascal et al., 1954), it is reasonable to assume that, after equilibration, these losses are proportional to the water losses through

these routes. Hurst et al. (1952b) reasoned that the renal tubules make no distinction in their reabsorption between deuterium oxide and water presented to them in the glomerular filtrate and showed that, in subjects given deuterium oxide intravenously or orally, at any given time after equilibration the deuterium oxide to water ratio of the serum was equal to the same ratio in the urine. This information has been put to use by our laboratory and a method for the determination of total body water by the urinary deuterium oxide to water ratio has been devised. A detailed description of this method will be found in Appendix I.

Methods Used to Assess an Individual's State of Hydration. The purpose of this section is to introduce the problems that one encounters when attempting to determine an individual's state of hydration and also to present a rationale for the use of a single water load test as a measure of the state of hydration. As a first approximation, water balance and gross weight changes can be used to determine the loss of total body water (Adolph, 1947). The disadvantage of using this sort of information is that such factors as caloric balance, insensible water loss, preformed and metabolic water, and changes in body composition serve only to confound an apparently simple situation.

In an extended study of acute water deprivation Adolph (1947) used the technique of gross weight changes to determine the loss of body water. Since all of his experiments were of short duration and his subjects were not allowed to urinate or defecate during the test periods he was justified in concluding that any weight loss was due to evaporative water loss with the reservation that the losses due to respiratory gas exchange and electrolytes lost in sweat present an error in their calculation of only one percent. It is true that thirst is a sign of dehydration, but it is not a reliable indicator in man. It is impossible to assess the degree of dehydration, by the intensity of thirst since the two are not quantitatively correlated. Adolph (1947) showed that man may voluntarily dehydrate to the extent of two percent of his body weight before the desire for water is present; and that it is possible for man to succumb to dehydration exhaustion without severe thirst. The urinary flow and specific gravity and body water deficiency are not good indices of dehydration, for reasons that will become apparent in the discussion to follow.

The most satisfactory procedure for the assessment of the degree of dehydration is one in which the total body water is determined when the subject is in his normal state of hydration and again when he has undergone dehydration. It must be borne in mind that even with total body water determinations before and after a water deprivation regimen we are only determining the amount of water present; we have no idea of changes in body composition or distribution of fluids. In order to assess the state of hydration with the greatest degree of accuracy, balance studies of water, nitrogen, and minerals must be made and extracellular fluid volume must be determined. Total body water determinations are more reliable as a measure of dehydration than are the other methods mentioned above but they are costly and time-consuming.

In field studies the difficulty of administering a diluent and collecting blood or urinary samples usually presents a serious burden for the investigator

and the experimental subjects. For this reason, a simple water-loading test was devised, a detailed account of which will be presented in another portion of this report. First, however, it is necessary to review the purposes to which water-loading tests have been put by other investigators.

Simple water-loading tests have been devised for two major purposes: first, to study adrenal cortical function and second, to study the state of renal function. It has been claimed that adrenocortical hypofunction can be detected by the manner in which a water load is handled (Levy et al., 1946). In this test no fluids or food are allowed after supper, the night urine is collected, a water load of 2% of the body weight is given orally in the morning and the next four hourly samples of urine are collected. If the volume of the night specimen is less than that of any of the hourly samples the subject, according to the authors, does not have Addison's disease. If the night urine sample is more than that of any of the hourly samples the test is inconclusive and the clearance of urea, chloride, and water must be determined. The magnitude of the sum of the products of the clearance ratios serves as an index to adrenal function.

Renal function has also been evaluated by a test which is similar in some ways to the adrenal function test (Mosenthal, 1915). Urine is collected for six two-hour periods during the day while patient consumes known volumes of water and one twelve-hour night sample while the patient drinks nothing. Each urinary sample is analyzed for volume, specific gravity, total nitrogen, and chloride. In this test a normal response is one in which the specific gravity figures vary at least nine points from the highest to the lowest, and the volume of the night urine is 400 ml or less. It has been stated that when kidney function becomes impaired the first signs are usually demonstrated by a large night urine volume. In cases of chronic nephritis there is a tendency to polyuria; the specific gravity becomes fixed at 1.010.

It is our contention that features which are presented as diagnostic aids in the above tests may merely reflect the state of hydration of the individual at the time. This type of test then may be used to assess an individual's state of hydration when renal pathology has been ruled out by other tests.

Pure Salt Depletion Dehydration. A parallelism exists between uncontrolled Addison's disease and pure salt depletion dehydration (Duncan, 1947) in that both conditions are characterized by a primary electrolyte imbalance followed by a decreased circulating blood volume and circulatory collapse. It is true that oral or intravenous water given to Addisonian patients or those suffering from pure salt depletion dehydration serves ultimately to provide a vehicle for the exodus of more electrolyte, but the question we are asking at this time concerns the events that occur immediately or shortly after the water load. Robinson et al. (1941) are of the opinion that if water loading does not result in a diuresis, adrenal hypofunction may be suspected. To confirm this opinion urea and chloride clearance studies were made, because in adrenal hypofunction urea retention, moderate water excretion, and a high chloride excretion are the signs found. In pure salt depletion dehydration, urea retention and moderate water excretion are also known to occur (Weisberg, 1953). The only real difference between the two is the excretion of high levels of

chloride and sodium by the Addisonian and very little electrolyte excretion in the salt depleted individual. Since both of these conditions are due to dehydration caused by salt imbalance, why then does not the same test of the ability to handle a water load as used in Addison's disease apply as well for the detection of salt loss dehydration?

Pure Water Depletion Dehydration. Pure water depletion dehydration is a condition which results from an imbalance of water---more water is being lost than is being taken in. This type of dehydration may be rapid or it may result from a chronic negative water balance. In acute water depletion there are suggestions that the degree of dehydration compatible with normal function is less than in the long term chronic type of dehydration. The exact cause of death in either of these conditions is unknown. Weisberg (1953) expresses the popular opinion that the mode of death in chronic water deprivation is due to a rise of osmotic pressure with respiratory failure. Acute water deprivation in man has been studied extensively by Adolph (1947), who finds that dehydration exhaustion occurs when a man has lost 5-6% of his body weight and further that this exhaustion is completely relieved by drinking water. Adolph points out that an acute loss of water, such as caused by sweating in a hot dry atmosphere, results in body changes that can be summarized as follows: the pulse rate and rectal temperature increase, breathing is faster, and the blood becomes more concentrated as the blood volume diminishes. The deleterious effects of acute water deprivation appear to be circulatory and very similar to those found in salt depletion dehydration and Addison's disease.

It has been shown by Nadel et al. (1941) and others that in chronic water dehydration, water is lost from both extra- and intracellular compartments. In the initial stages of water depletion extracellular volume is maintained at the expense of intracellular fluid. When the water deprivation is mild, the kidney excretes salt equivalent to the amount of water lost. There is evidence of a depletion of total body water and total body salt, but the osmotic pressure relationships within the body are preserved (Peters, 1937-38). With further depletion of water the extracellular fluid becomes hypertonic, renal regulatory mechanisms come into play and water is reabsorbed. The urinary osmolar concentration increases and levels off at some value commensurate with the maximal concentrating ability of the kidney. Due to the altered osmotic relationships within the body there results a shift of water from the intracellular into the extracellular spaces. The mechanism for this shift of fluid is not known; it is assumed at the present time to be due entirely to differences of osmotic pressure. It has been demonstrated in this connection that as dehydration progresses there is a loss of cellular potassium (Elkington and Taffei, 1942) which is presumed to occur as an attempt on the part of the organism to minimize the hypertonicity which results from the loss of cellular water.

Water presented to an individual undergoing simple water dehydration during either acute or chronic deprivation will alleviate all of the symptoms (Adolph, 1947). The amount of water necessary depends upon the degree of dehydration (Adolph, 1947). It has been shown (Black, McCance and Young, 1944; Nadel et al., 1941) that osmotic retention occurs as water deprivation progresses. However, it has never been demonstrated whether the amount of water

necessary to relieve the symptoms of water deprivation bears any relationship to the degree of osmotic retention or whether the onset of diuresis coincides with the elimination of retained substances.

Mixed Water and Salt Depletion Dehydration. A third type of dehydration is recognized in which both the signs and the symptoms of pure salt and water depletion dehydration are manifest. This type of dehydration, known as mixed water and salt depletion dehydration, is usually associated with alterations in acid-base balance and found in patients who are losing large amounts of body secretion. In the latter situation water loss is usually greater than salt loss, since the gastrointestinal fluids are isotonic, sweat, hypotonic, insensible loss, almost pure water, and urinary tonicity, variable---probably quite hypertonic in these cases.

As a consequence of this type of dehydration, there occurs a reduction in the extracellular fluid volume; but since the water loss is greater than that of the electrolytes, the extracellular compartment becomes hypertonic and water is lost from the intracellular space. The clinical picture is that of circulatory collapse with the other signs and symptoms of a reduced extracellular volume. The signs of pure water depletion, such as thirst and early oliguria, will also be present.

The Water Tolerance Test Used for the Assessment of State of Hydration. The possibility of using a water loading technique to estimate the degree of dehydration was first presented when adrenal function and renal concentrating ability were being studied in another ration trial (Med. Nutr. Lab., 1948). The investigators were attempting to assess adrenal and renal function by a combined water loading test. Although their experimental situation did not involve dehydration as such, they felt that the interpretation of the results of the water loading test could have been affected by dehydration of the subjects. In the rationale for the water tolerance test as a measure of dehydration given above, we have pointed out that if renal concentrating ability is normal, the volume of urine produced as a result of a water load is dependent upon the hydremic condition rather than upon any endocrine hypofunction per se.

In the present study the water tolerance test was performed in conjunction with estimates of total body water; by this procedure we felt it would be possible to quantitate the water tolerance test. The water tolerance test punctuated the ending of each pre- and experimental period. Total body water determinations were carried out shortly before the ending of each of these periods. By this approach both normal and experimental data could be obtained on the total body water and percent recovery of a water load. From these data a quantitative appraisal of the water tolerance test as a measure of the state of hydration could be made.

Unfortunately it was not possible to conduct the water tolerance test in identically the same manner in both the temperate and winter phases of the study. During the temperate study of 1953, the subjects were neither confined to a fixed position nor were they required to abstain from smoking. Both of these factors have been shown to influence the rate of urine formation (Burn

et al., 1945; Smith, 1951). During the winter phase the subjects were confined to their beds and were not allowed to smoke for the duration of the test period. The diurnal variation in urine production was ruled out as a possible variable by always performing the test at the same time of day.

Oral Dose of Deuterium Oxide in Water. During the winter phase of this study two body water determinations were made on each of 95 subjects. Two oral doses of deuterium oxide in water were given (Table II. 26). Each subject received the same amount of the deuterium oxide-water solution and

TABLE II. 26

PROTOCOL FOR ADMINISTERING HEAVY WATER AND COLLECTING URINARY SPECIMENS FOR MEASUREMENT OF BODY WATER

Equipment:

1. Canteen cups
2. Two 100-ml graduates
3. Heavy water appropriately diluted with tap water

Procedure:

1. On Day 9 of the pre-period and Day 10 of the experimental period, all 24-hour urinary specimens will be labelled "Pre-D_2O."
2. On Day 10 of the pre-period, all subjects will be given 40 gm of 98% heavy water diluted to 100 ml.
   On Day 11 of the experimental period, all subjects will be given 20 gm of 98% heavy water diluted to 100 ml (Figure II. 35).
   Both these doses will be administered before the evening meal. The 22- or 24-hour urinary specimens will be labelled "D_2O-Day."
3. On Day 11 of the pre-period and Day 12 of the experimental period, the 22- or 24-hour urinary specimens will be labelled "Post-D_2O."

Disposition of Specimens:

1. The three properly labelled specimens of urine will be shipped to McKinley Hospital.
2. On receipt at McKinley Hospital, 50 ml of undiluted urine will be taken from each of the three urinary specimens. Into each of two labelled 1 oz bottles transfer 25 ml.
3. Store aliquots at McKinley Hospital until time for analysis.

no allowance was made for body habitus. For the pre-period body water determination approximately 40 gm of 99.5% pure deuterium oxide was given to each man; for the measurement body water in the experimental period a booster dose of 20 gm of 99.5% pure deuterium oxide was given to each man. The deuterium oxide was diluted with water so that exactly 100 ml of solution would contain approximately 40 gm in the one case and 20 gm of pure deuterium oxide in the other.

After an oral dose deuterium oxide equilibrates with the body fluids in approximately 3.5 hours (Hurst et al., 1952a). Upon reaching equilibrium within

FIGURE II. 35. SUBJECTS OF FLIGHT 1 RECEIVING DEUTERIUM OXIDE FOR BODY WATER TEST. FOREGROUND: CAPT. F. SARGENT, II, A/3C R. V. JONES, AND MISS M. JACKSON.

the body fluids, the deuterium oxide to hydrogen oxide ratio in the blood and urine are equal. After equilibration the urinary deuterium oxide level can thus serve as an indicator of the volume of dilution undergone by this test solute; from this information the total body water can be calculated (Table II. 27). The samples to be analyzed for D_2O were obtained from the 24-hour urinary specimens.

TABLE II. 27

STEPS FOR CALCULATIONS OF D_2O SPACE

1. Collection period = 24 hrs for subjects or known time for cadre.
2. Volumes are recorded in ml.
3. D_2O in original is determined by dropping against one set of weighed standards, expressed as gm D_2O/100 ml.
4. D_2O lost in urine (gm) =
   (D_2O in original urine, gm/100 ml) x (Volume in ml).
5. D_2O lost in insensible perspiration (i.e., IW, gm) =
   (0.7 ml IW/kg body weight/hr) x (PRE-body weight in kg) x (D_2O in

original urine, gm/100 ml) x ($\frac{1}{100}$) x (hrs of collection).

6. Correction for urine blank is the average of Flight 1 Pre-D_2O (Day 9), corrected for decay on basis of 5 subjects who came off early.
7. Dosage on M 3 was 35.3 gm. Dosage on M 17 was 16.9 gm.
8. On M 4, D_2O space (liters) = (D_2O remaining, gm) ÷ (D_2O ratio - 0.0045).
9. On M 19, D_2O space (liters) = (D_2O remaining, gm) ÷ (D_2O ratio, corrected for decay on M 17, 18, and 19 - 0.0045).

The deuterium oxide drink was given before supper on a day designated as the "D_2O Day". The urinary samples saved for analysis were stored at room temperature in screw-cap amber bottles. These samples were aliquots of the pre-D_2O, D_2O, and post-D_2O days. The pre-D_2O Day provided the urinary blank; the D_2O Day provided the pre-equilibration loss of D_2O; and the post-D_2O Day provided the ratio of deuterium oxide to hydrogen oxide from which the total body water was determined.

Estimation of Deuterium Oxide in Urine. The method of obtaining pure deuteriated water from urine and measurement of the D_2O/H_2O ratio in that water has been described in detail in Appendix I.

Water Diuresis Test. The protocol followed in this test is given in Table II. 28. The method of calculating the net recovery was the same as that described in WADC TR 53-484.

TABLE II. 28

PROTOCOL FOR FIELD WATER DIURESIS TEST

Equipment:

1. 6 1-liter pharmaceutical graduates
2. 100 tin cans with 2000 ml capacity
3. 500 tin cans with 500 ml capacity
4. 4 500-ml graduated cylinders

Procedure:

1. The subjects will drink all their water allowance on the day prior to the test by 1800. They will not collect a special night urine.
2. They will void as usual at 0630 completing their 24-hour period. There will be no smoking until 1200.
3. They will receive no breakfast. They will eat 50% of calories at lunch and supper.
4. They will be handled by major groups of 22 men plus three observers each.
5. Each group will report to the assigned station at 0700.
6. They will recline during the entire test period.
7. At 0800 they will void into appropriately labelled cans (500 ml capacity). The voiding will be "by the numbers."
8. The oral dose will be administered between 0800 and 0845, the load having been prepared for each subject ahead of time: (Wt (kg) on day

prior to test) x (20 ml/kg) = (total water load). These loads will be placed in cans of 2000-ml capacity labelled with subject's code number. The load will have been consumed within the period 0800-0845.

9. They will void into separate labelled containers at 0900, 1000, 1100, and 1200. Voidings will be "by the numbers."
10. After the voiding at 1200 they will report to messing stations for noon meal.

Disposition of Specimens:

1. The volume of urine in the five specimens from each subject will be measured and recorded in the appropriate form. The specimens may then be discarded.

Records:

1. The times of voiding beginning at 0630 will be recorded.
2. The oral load will be recorded.
3. The volumes of urine will be recorded.
4. The urine flow will be calculated as ml/hr.

3. Body Fat

The percent body fat and the kilograms of body fat were calculated from measurement of the skinfold thickness as discussed by Sargent et al. (1954). The measurements were made by the medical officers during the two-hour test.

Prior to beginning the experimental period and at the end of the experimental period, two photographs were taken (front view and profile) of each subject. These photographs were used to appraise qualitatively the loss of body tissue caused by the several experimental regimens. Examples of these alterations will be given in Section III; Results.

L. PHYSICAL FITNESS

A half-mile run was established as a test of physical fitness (Table II. 29). Three criteria were available for judging the results of this test: (1) whether or not the subject was able to complete part or all of the run, (2) the time required to cover the course and (3) the pulse rate at the end of the test (Figures II. 36 and 37). Interpretation of these objective data, however,

TABLE II. 29

PROTOCOL FOR PHYSICAL FITNESS TEST

Equipment:

1. Stop-watches, four
2. One-half mile course on level terrain

Procedure:

1. The subjects will be clothed in comfortable "fatigues," appropriate for the existing weather.
2. They will be tested by major groups of 22 men. One group being

FIG. II. 36

FIGURE II. 36. HALF-MILE RUN, CAMP McCOY, WISCONSIN, WINTER, 1954. SUBJECTS OF FLIGHT 3 WAITING THEIR TURNS.

tested at a time: 1300-1500, 1500-1700.

3. Five observers will be required: one to start subjects and four to time subjects, count pulse, record data.
4. Subjects will run four at a time over course.
5. Pulse rate will be counted at the interval 1-2 minutes after subject completes run.

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revolved on knowledge of the effort expended by the subject in performing the test. Was the subject sufficiently motivated to make an "all out" effort or did he merely go through the motions? This matter of motivation is an essential consideration in all tests of physical fitness in which the subject is required to perform a burdensome task. Motivation is difficult to measure quantitatively; usually the best one can do is rely on subjective impressions. In the test we used there was no incentive in terms of a reward. We relied completely on team esprit de corps and a spirit of competition among groups. The flight leaders and the medical officers were the individuals who were expected to lead in the development of these motivating attitudes.

Two other significant variables in interpreting the results of this test of physical fitness were the condition of the track and the state of the weather, especially the wind velocity. The length of the course was measured

FIGURE II. 37. COUNTING PULSE AFTER HALF-MILE RUN, CAMP McCOY, WISCONSIN, WINTER 1954. LEFT TO RIGHT: A/3C NORMAND, A/2C LIGHTNER, AND A/3C PORTER.

with the mileage meter of a car. Such devices are usually reliable within ±10%. At Chanute AFB, the test was conducted on a cinder track. During both pre- and recovery periods, there was no snow-cover (Table II. 30).

TABLE II. 30

TRACK AND WEATHER CONDITIONS FOR HALF-MILE RUN

Condition	PRE	EXP	REC
Track	Cinder	Packed snow	Cinder
Weather	Clear	Cloudy	Clear
Wind velocity, m.p.h.*	8	7	8
Temperature, ^{o}F	39	25	65

*Measured at track at height of six feet above ground

At Camp McCoy, a course was measured in a large sand and gravel covered parking lot. On the day of the test this surface was covered with packed, rather slippery snow (Table II. 30; Figure II. 36). During all three tests the wind was gusty, averaging between 7 and 8 m.p.h. The temperature was considerably higher during the recovery period than during pre- and experimental periods.

To obviate the possibility of training influencing the results of the

bi-weekly tests, all subjects ran the half-mile against time two or three times in the week (15-22 Feb.) prior to beginning the investigation. Since training did not appear to have influenced the results during the course of the six weeks of the study, the results of these indoctrination runs will not be reported.

M. CLINICAL OBSERVATIONS AND METHODS

Each subject was given three complete physical examinations. The first physical examination was conducted early in the pre-period. Prior to this time each subject had a chest X-ray taken. After these physicals the X-ray reports were reviewed and the suitability of each subject as a safe medical risk was decided. One subject (No. 62) had chronic healed tuberculosis. He was switched from ST 0 to 15/52/33 1000 on the grounds that the risk of a breakdown would be lessened. Subject 58 had chronic bronchial asthma. Since he responded well to symptomatic treatment, it was decided to retain him as a subject. Subject 81 was under treatment for syphilis. The Venereal Disease Control Officer of Chanute AFB saw no reason why the subject could not serve during the winter trials. No other significant abnormalities were discovered and so all the volunteers were retained. A second physical examination was made at the end of the experimental period. The final examination was conducted in REC II.

All examinations were made by the medical officer assigned to the flight. The examinations were conducted according to standard procedures of physical diagnosis (e.g., Pullen, 1944). Relevant histories were obtained at the same time. The observations were noted on special forms designed for the winter trials (Appendix VI).

Daily progress notes were maintained by the medical officers on the subjects in their flights. These notes documented both spontaneous and elicited complaints with reference to the health and well-being, physical and psychological, of the subjects, together with observations of the medical officer on the condition of the subjects individually or as a group.

Medication was given to the subjects as indicated, but the use of aspirin was maintained at a minimum. Antibiotics were used for management of upper respiratory infections, terpin hydrate for coughs, and kaopectinate and paregoric for diarrhea. Diagnostic procedures and hospitalization either at Chanute AFB or in the field sick bay were employed when circumstances so dictated. The case histories of the 87 subjects are given in Appendix III.

N. COMBINED TESTS

Because of the large number of subjects to be tested, it was necessary to devise systems for obtaining rapidly and accurately the desired metabolic and functional information. The many procedures described in the preceding pages were grouped into several tests, which we have called "combined tests". The protocols for these tests, as they were successfully employed during the winter trials, are discussed in the paragraphs to follow.

1. Two-Hour Test of Organic Function

The protocol for this test is detailed in Table II. 31. In this two-hour period (Figure II. 38) information was collected on (1) hematology, (2) cardiovascular function, (3) liver function, (4) renal function, (5) and body composition. Validation of the procedures and details regarding the analyses have been described elsewhere in the report. The two-hour test was supervised by Capt. W. Mandel, USAF(MC).

TABLE II. 31

PROTOCOL FOR TWO-HOUR TEST

Equipment:

1. 100 paper cups with 4-oz capacity
2. 100 one pint cans with screw-capped closure
3. 200 50-ml centrifuge tubes
4. 100 oxalated screw-capped vials
5. 400 30-ml syringes, clean, dry, sterile
6. 200 sterile 19-gage needles
7. Rubber tourniquets
8. 70% ethyl alcohol
9. Sterile sponges (2 x 2" cheese cloth)
10. 1 sphygmomanometer and stethoscope
11. Portable Instomatic Cardiette
    a. spare batteries
    b. spare fuses
    c. spare loaded film magazines
12. Observer's own wrist watch
13. Calipers for measuring skinfold thickness

Procedure:

1. Subjects will be postabsorptive during test.
2. The test will be conducted, in the experimental period, according to the scheme below, and will require two hours per group: 0700-0900, 0900-1100, 1300-1500, and 1500-1700. In the pre-periods and recovery periods all subjects will be tested in the afternoon of two consecutive days.

SCHEDULING OF TWO-HOUR TEST ACCORDING TO EXPERIMENTAL NUTRIENT MIXTURE

Time of Test	0700-0900	0900-1100	1300-1500	1500-1700
Sub-groups to be tested	ST.0(16) A-1 (8) A-2 (8)	C-1 (8) C-2 (8) D-1 (8)	B-1 (8) B-2 (8) D-2 (8)	D-3 (8) Observers (12)
Number of subjects	32	24	24	20

3. Those men being tested at 0700-1100 will not receive breakfast. Those men being tested at 1300-1700 will receive breakfast but will not receive lunch. No coffee, tea, or cocoa will be consumed in the four hours prior to testing or during the test.
4. On days of this test 50% of calories will be fed at two meals.

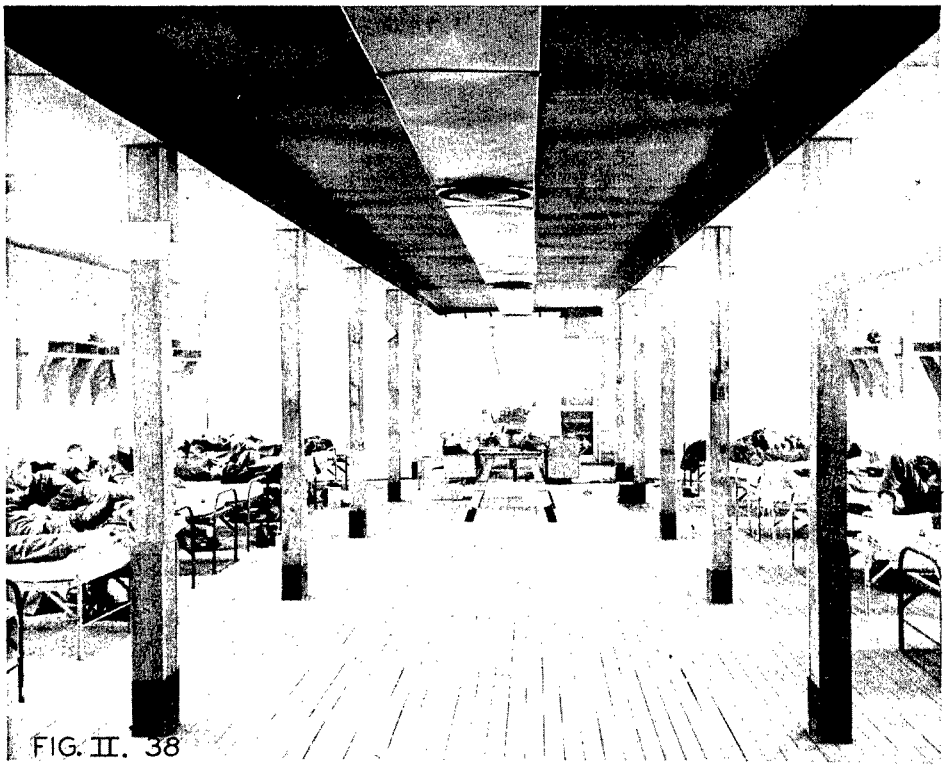

FIGURE II. 38. CLINICAL TESTING AREA, CAMP McCOY, WISCONSIN, WINTER, 1954. SUBJECTS OF FLIGHT 3 DURING TWO-HOUR TEST.

5. Twenty-five subjects will report to test-station at the assigned times. They will void "by the numbers," into their 24-hour specimen containers. The exact time will be recorded.
6. They will drink 100 ml of water.
7. They will lie down for 15 minutes.
8. After a 15-minute rest-period, the blood pressure, pulse rate, electrocardiogram, and skinfold thickness will be measured by observers assigned the specific duties.
9. During the second hour a venipuncture will be made on each subject; minimal stasis; 75-80 ml sample, 5 ml of which will be oxalated. The time of venipuncture will be recorded for each subject.
10. The subjects will void at the end of 120 minutes into the labelled one pint cans, the exact time of voiding being recorded. (If the subject cannot void at 120 minutes he will be required to remain at the station until he can).
11. The blood specimens and urinary specimens will be delivered to the clinical laboratory station promptly for testing and handling.

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2. Resting Metabolism Test

The protocol for this test is detailed in Table II. 32. During the course

TABLE II. 32

PROTOCOL FOR RESTING METABOLISM TEST

Equipment:

1. Electroencephalograph
   a. scalp electrodes
   b. electrode paste
   c. spare rolls of recording paper
2. Stop watches, two
3. Two sets of three gasmeters and accessories
4. Four cots, one in each of four rooms

Procedure:

1. The subjects will be taken four at a time.
2. They will not be postabsorptive.
3. Two subjects will begin test 30 minutes ahead of the other two. Thereafter, pairs can be run continuously through the sequence detailed below.
4. The tests will be conducted on each of two days between 0730 and 2030 by four teams of observers according to scheme shown below. The same subject will be tested at the same time of day during each of the six tests.

SCHEME FOR CONDUCTING RESTING METABOLISM TEST

Time	Team A&B	Team C&D	Team Working Time
0730-0830	1	1	0730-1230: A&C on
0800-0900	1	1	first day and B&D on
0830-0930	1	1	second day.
0900-1000	1	1	
0930-1030	1	1	
1000-1100	1	1	
1030-1130	1	1	
1100-1200	1	1	
1130-1230	1	1	
1200-1300	1	1	1230-1830: B&D on
1230-1330	1	1	first day and A&C on
1300-1400	1	1	second day.
1330-1430	1	1	
1400-1500	1	1	
1430-1530	1	1	
1500-1600	1	1	
1530-1630	1	1	
1600-1700	1	1	
1630-1730	1	1	
1700-1800	1	1	
1730-1830	1	1	
1800-1900	1	1	1830-2030: A&C on
1830-1930	1	1	first day and B&D on
1900-2000	1	1	second day.
1930-2030	1	1	

5. The subject will recline for 30 minutes.
6. During the first ten minutes of the rest, place electrodes and measure the passage of time. During the last twenty minutes record the electroencephalogram first on one subject and then on the second subject.
   a. Passage of time: The subject will be handed a stop watch face down and asked to estimate the passage of time-interval stated by the observer. When the subject is ready, he will activate the stop watch; when he judges the stated interval to have passed he will stop the watch and return it to the observer face down. The time will be recorded; the watch zeroed and returned to the subject. The subject may use any mental device he wishes to judge the interval. He must not use his pulse or respiratory rate. He must not be informed of his judgements at any time. The stated intervals will be 20 seconds, 45 seconds, and 70 seconds in that order, one trial being allowed per interval.
   b. Electroencephalogram: This will be obtained only in week 2 and week 4. The recording electrode will be attached to the scalp above the occipital lobe, the reference electrode to the scalp above the ear. A three-minute record will be made while the subject is resting with eyes closed, then with the record still progressing the subject will hyperventilate for three minutes, and finally three minutes of record post-hyperventilation will be obtained. The three phases will be identified as R, H, and PH on the record together with the subject's number and the date and time of the test.
7. The subject will arise and move leisurely into an adjacent room and lie down on the cot.
8. The subject will breath through the gasmeters for five minutes to flush the meters.
9. For ten minutes more, the pulmonary ventilation, oxygen consumption, and CO_2 production will be measured.
10. Record gas temperature and station-level barometric pressure.
11. Repeat steps 9 and 10.
12. Calculate pulmonary ventilation (l/min), oxygen consumption (ml/min), and CO_2 production (ml/min) at S.T.P.
13. Calculate respiratory quotient:

$$R.Q. = (CO_2 \text{ Production})/(O_2 \text{ Consumption})$$

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of the procedure information was collected on (1) pulmonary ventilation, (2) resting oxygen consumption, (3) resting R.Q., (4) subject's judgement of the passage of time, and (5) electroencephalogram. The resting metabolism test was supervised by Dr. W. A. Boyd.

3. Program of Testing Subjects Coming off Experimental Diets Early

It was anticipated that some of the subjects might have to be taken off the experimental regimens before the completion of the 14-day period. Since this exigency might arise at any time, it was essential that a plan be

available for conducting all the function tests concurrently. The plan adopted is detailed in Table II. 33 and combines all the important steps of the water diuresis, two-hour, and resting metabolism tests.

TABLE II. 33

TESTING PROGRAM FOR SUBJECTS COMING OFF EXPERIMENTAL REGIMENS BEFORE COMPLETION OF 14 DAYS

1.	Void into gallon cans; note exact time. Label pre-D_2O
2.	Drink 100 ml H_2O
3.	Run steps 7, 8 and 9 of 2-hour test
4.	Run resting metabolism test
5.	Void into pint can at approximately 120 min; note exact time
6.	Conduct steps 8 and 9 of water diuresis test, includes 20 ml D_2O in the oral water load
7.	After measuring four hourly urine volumes, pool, mix, and save 4 one-ounce aliquots. Label D_2O
8.	Allow no more food or water according to severity of individual case and collect urine in fresh gallon can until end of 24-hour period. Measure volume and save 4 one-ounce aliquots. Label post-D_2O

O. STATISTICAL METHODS

Statistical procedures similar to those used in analyzing the data of the 1953 study were repeated during the study of observations and data collected in the 1954 winter trials. Because of the importance of the concepts of control used in these two studies, we shall reiterate the material published in the report of the first trial (Sargent et al., 1953).

1. The Concept of Own-Control

The design of the present investigation was that common to all clinical investigation; viz., repetition of critical observations on the subject in a pre-period, an experimental period, and a recovery period. This device might be identified as the concept of "own-control". Each subject serves as his own control in that the observations can be assessed by comparing the data of the pre-period with those of the pre-period and recovery period. By this device the measurements of the pre-period can arbitrarily be equated to 100 and the data of the experimental and recovery periods expressed as a percentage of the pre-period measurement. The results of the several critical observations are thus expressed in units independent of the original observations and the order of magnitude of deviations from the pre-period or control values becomes readily apparent.

It is a known fact that individuals differ one from another with respect to the exact value of a given physiological or biochemical measurement. This inter-individual variability --- the so-called normal range --- may prejudice statistical analyses when absolute values are used in the mathematical

treatment. On the other hand, the concept of own-control allows this potential bias to be minimized. When the individual control data are set equal to 100, the changes in the experimental and recovery periods can be expressed as averages which are not prejudiced by the influence of one individual. This mathematical procedure was used in studying the effects of the several experimental regimens on a great many of the functions of organs and systems and different biochemical levels in the several biological fluids.

2. The Concept of Positive and Negative Control

Reference standards had to be established for interpreting the data collected while the subjects subsisted on the several experimental nutrient mixtures. By definition a fixed intake of 3000 Cal/man/day was identified as the "positive control". (In the winter of 1953 this regimen was made from components of the 5-in-1 ration; in the 1954 winter trials the 15/52/33 regimen was fed at 3000 Cal/day.) This regimen was pictured as that most closely approaching the subjects' usual diet. The distribution of calories approximated those of the pre- and recovery periods and was very similar to that reported for voluntary food consumption by troops residing in temperate climates (Johnson and Kark, 1947). Subsequent analysis of the data on caloric expenditure indicated that the men in Flight 3 (Light work, unlimited water) used up about 3000 Cal/day. These subjects of this flight who subsisted on this regimen lost relatively little body weight during the 14-day interval on this regimen. Most of the functional data showed little change. In general, then, this positive control fulfilled our idea of a reference standard. A negative standard was also needed. By definition starvation was pictured as the "negative control". This regimen produced marked changes in body weight, nutrient balances, and the functions of organs and systems. It was hoped that the physiological reactions to the several experimental nutrient mixtures would fall somewhere within the range delimited by positive control and negative control. The more nearly the reactions approached those of positive control, the less presumably was the nutritional stress. The more nearly the reactions approached those of negative control, the greater presumably was the nutritional stress. Perhaps evaluation of the data within this conceptual frame would lead to practical information regarding the feasibility of an all-purpose or at least a multi-purpose survival ration.

From the statistical point of view, then, positive and negative control can be visualized as the upper and lower limits of variation in physiological processes and biochemical levels in this investigation. Generally speaking, positive control was the optimum nutrient mixture. It should follow, then, that a measurement expressed as a percentage of the pre-period average should remain, within the limits of experimental error, at 100% in the experimental and recovery periods. The maximum deviation, plus or minus, from 100% should occur in negative control --- except when subsisting on a given mixture may be worse than eating nothing! The other nutrient mixtures should give values within the limits described by positive control and negative control. The differences between the measurements made during the 1000- and 2000-Calorie regimens and those made in the control regimens can be evaluated statistically and assist in drawing conclusions regarding the best possible nutrient mixture for survival. This attitude of mind has been adopted in this investigation in

the analysis of the entire body of observational material.

3. The Concept of Ration Control

Although a packaged ration, such as the 5-in-1 ration, may provide an adequate control ration, it is still not a "normal" diet. The usual diet of Americans does not consist entirely, or even largely, of packaged items. Thus, the 5-in-1 components do not provide an ideal control ration. Furthermore, the components of this ration are not merely packaged but processed to meet special military specifications regarding stability and utility under conditions not ordinarily encountered by ordinary commercially packaged items. To our knowledge there is no adequate proof that a diet of rations prepared to meet military characteristics has the same nutritional and physiological effects on man as a diet comprised of foods customarily eaten by Americans. A rigorous test has never been made in which subjects living on the 5-in-1 ration, for instance, have been compared with subjects living on standard garrison A rations. Because a doubt was present, in our minds at least, regarding the 5-in-1 ration, we requested the flight leaders, who were to subsist on their customary diets throughout the winter trials, to serve as subjects. These men, whom we called ration controls, took part in all the activities and tests that the members of their respective flights did. There were only two differences: (1) the ration controls chose ad libitum from foods regularly available in USAF mess halls and (2) they were allowed water ad libitum.

Theoretically, any differences, with regard physiological function and biochemical levels, between the ration controls and the volunteer subjects should represent the effect of the packaged ration (i.e., 5-in-1). In practice, however, a strict comparison may not be possible for the flight leaders represent a somewhat older age group than the volunteer subjects. Where the influence of age can be ruled out, the observations should constitute a significant contribution to our knowledge of military nutrition.

The ration controls also served two other useful purposes. In the first place, any trends due to the procession of the seasons would be reflected by the ration controls. In the second place, non-specific reactions to the several conditions of the trial would be reflected by the ration controls. Such information would provide a basis for deciding whether or not a given nutrient mixture rather than the work load or the non-specific factors of the trial was the cause of a significant alteration of a physiological process or a biochemical level.

4. Statistical Analyses

Throughout the report the statistical procedures and terms are the same as those described by Rider (1939) and Croxton (1953).

Average and mean are used interchangeably and in both cases refer to the arithmetical mean.

The variance of a set of data from the mean has been measured in two ways: (1) standard deviation and (2) coefficient of variation. The standard deviation

has been calculated from the equation: $(s.d.)^2 = \frac{1}{N} \Sigma (X-\overline{X})^2$ where s.d. = standard deviation.

The coefficient of variation was calculated from the equation: $C.V. = \frac{(s.d.)}{M} \times 100$ where C.V. = coefficient of variation and M = arithmetical mean.

The "t" test was used to analyze the significance of the difference between means. The Chi Square test was employed to determine the statistical significance of changes in frequency distributions. The data of a number of tests was submitted to analysis of variance. Most of these analyses were kindly performed by Dr. Leon E. Harter of the Wright Air Development Center. His work will be discussed in the appropriate parts of Section III: Results.

5. Validation of All Methods

Most of the procedures used in this investigation were validated in the hands of the individual responsible for the particular method. In some instances, validation was rather elaborate. In the case of all chemical methods, recovery studies were performed. In general ten recovery experiments were done before results were accepted as satisfactory. In all such cases the material recovered was 95-105% of that added.

SECTION III

RESULTS

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

A. INTRODUCTION

1. General Remarks

This report presents the results of metabolic investigations made upon 87 volunteer airmen and 12 ration controls who served as group leaders. During the 42 days of continuous observation food and water intakes were measured daily, all urine and feces were collected, blood was drawn weekly, functional tests were conducted weekly, and complete physical examinations were made once every two weeks. Since the objective was to evaluate the effects of 40 different experimental regimens on the efficiency of the body as a whole and changes in the function of organ systems, many different kinds of data were recorded for each subject. Some 10,000 analyses, mostly in duplicate, were made on blood or serum; urine required an additional 10,000 measurements, all in duplicate; feces required another 4,000 measurements, all in duplicate. The various functional tests accounted for some 9,000 observations. Daily entries were made for each of the 87 subjects for 17 quantitative aspects of the nutrient intake. For these nutritional figures a quarter of a million intermediate calculations resulted in some 62,000 final entries. Overall, the 87 subjects and 12 ration controls required 95,000 individual accurate quantitative entries from which numerous averages, ratios, and statistical analyses and graphs were prepared for the present section.

In the main, results will be presented according to the organs and systems of the body which were studied. In each part of the text dealing with a particular system or organ, the material will be subdivided according to experimental nutrient mixture, and further subdivided according to work output, whether hard or light. Original data will be summarized in figures and tables similar to those presented for the temperate study of 1953 giving means and various measures of variance. The actual original data will be found in various appendicies. The integration of this large mass of data leading to conclusions regarding the optimum nutrient mixture for survival under temperate and cold conditions will be dealt with in Section IV: Discussion.

2. The Weather

Since the basic objective of the study was to expose human subjects to cold weather under field survival conditions, the pertinent weather data will be presented at this point. Figure III. 1 contains daily swings of temperature in all phases of the study with mean maxima and minima for each of three two-week periods. At Chanute AFB the subjects were outdoors only about three hours a day, and the rest of the time they were in heated buildings. At Camp McCoy

the subjects were indoors only for meals and testing; the rest of the time they were outdoors protected only by clothing, tentage, and sleeping gear. It will be seen that the desired cold conditions were realized, the mean daily temperature for two weeks at Camp McCoy averaging just under freezing. Detailed weather data will be found in Appendix V.

3. Daily Work Load

In addition to the weather another major consideration controlled the daily planning of the study: daily work load. It was planned to study two kinds of survival situations. The first requires the castaway to escape and evade by travel; the second requires the castaway to remain in one spot surviving there until rescued. In the field phase of the present study, half the subjects simulating escape and evasion by marching 12 miles a day while the other half were remaining almost sedentary. The results of the study did emphasize many significant differences between these two kinds of survival.

B. BODY COMPOSITION

1. Body Weight

Weight Changes of Controls. The flight leaders of each of the four flights were weighed two or three times at intervals during the three two-week periods. These weights were taken as part of the resting metabolism test and the water diuresis test. The mean values for the pre-period, experimental period, and recovery periods are summarized in Table III. 1. The significant observation is that these control subjects did not lose weight during the experimental period; rather the majority tended to gain weight even though six of them were performing hard work at this time.

Experimental Subjects. With respect to body weight the four flights were remarkably uniform; the weight of all subjects tended to remain constant in the two weeks of the pre-period (Table III. 2).

The daily weight changes from the pre-period means are depicted in Figures III. 2 and 3 for each experimental regimen. Weight loss occurred during each experimental regimen, ranging from seven kg for ST 0 to one kg for N-3000. The weight loss tended to be progressive throughout the experimental weeks.

The mean maximal weight loss, was calculated by deducting from the mean weight for week 2 the lowest weight reached during the experimental period and then averaging values for individual subjects. Data for subjects 1, 4, 47, 60, and 68 were not included, for these subjects were removed from the regimen before the completion of the 14-day period. A few generalizations from Table III. 3 can be made (1) Fasting subjects lost the most weight and men on 3000 Cal/day the least. (2) There were no consistent differences between subjects doing hard work and those doing light work when water was unlimited; the former lost more weight when water was limited. (3) Regimens with low solute load

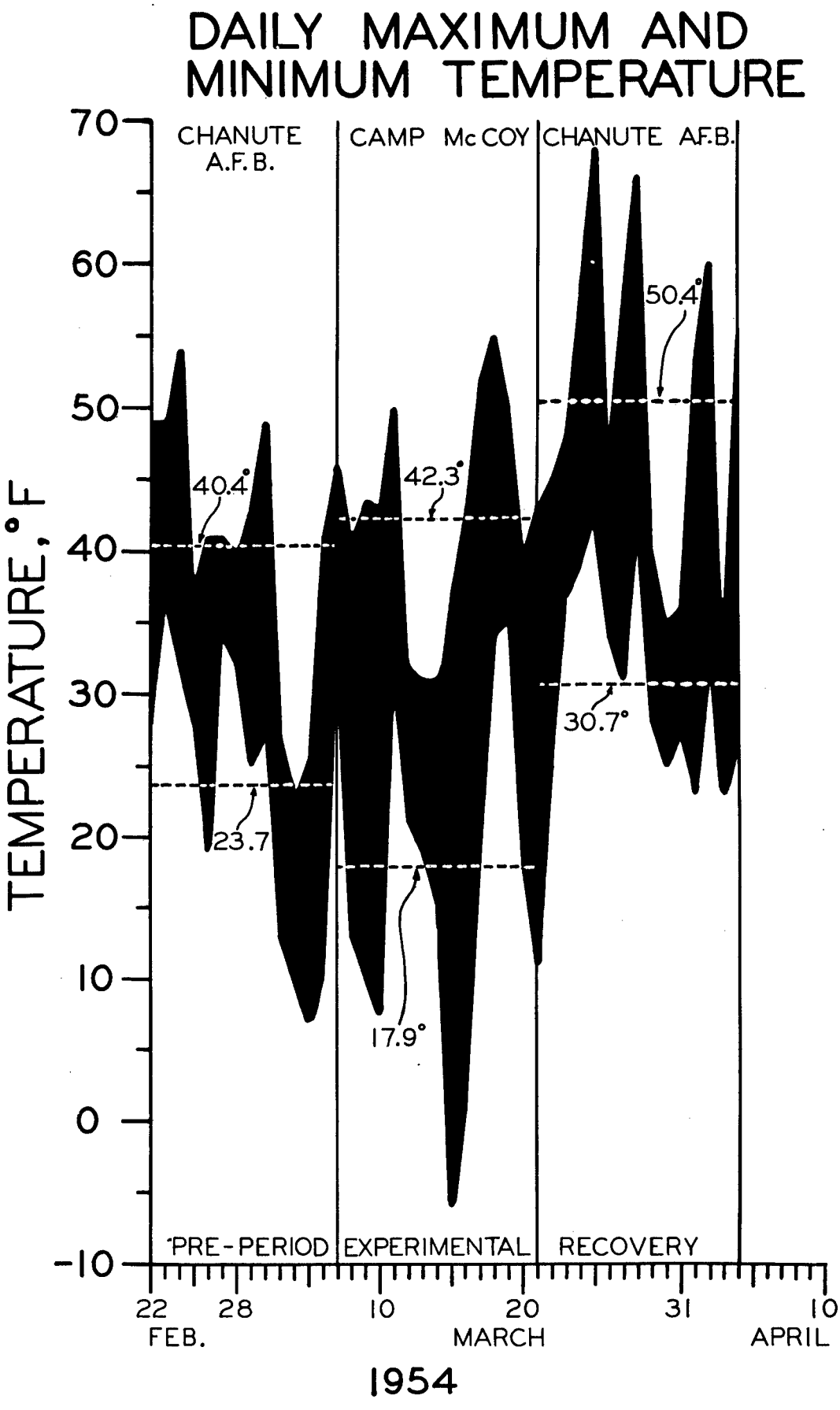

DAILY MAXIMUM AND MINIMUM TEMPERATURE
CHANUTE A.F.B.
CAMP McCOY
CHANUTE A.F.B.
TEMPERATURE, °F
70
60
50
40
30
20
10
0
-10
40.4°
42.3°
50.4°
30.7°
23.7
17.9°
PRE-PERIOD
EXPERIMENTAL
RECOVERY
22
28
10
20
31
10
FEB.
MARCH
APRIL
1954

FIGURE III. 1

(fasting, 0/100/0, and 2/20/78) caused little differences in weight loss when men on limited water were compared with those on unlimited water. (4) Regimens with high solute loads (15/52/33 and 30/0/70) generally caused a greater loss of weight by men on limited water than by men on unlimited water.

During recovery most of the weight loss was made up within the first week (Figures III. 2 and 3). During REC II there were fluctuations of body weight. There was, however, a striking tendency for the body weights to level off. In REC II groups of subjects were in strong positive calorie balance, even reaching some +4000 Cal/man/day. This phenomenon poses the intriguing question of why there should have been no weight gain in the face of such large positive caloric balance.

TABLE III. 1

MEAN BODY WEIGHTS OF CONTROL SUBJECTS
DURING SIX WEEKS OF STUDY
(kg)

Subject Code No.	Week 1 & 2	Week 3 & 4	Week 5 & 6
	Hard Work in Week 3 & 4		
90	74.1	74.4	73.3
91	91.6	92.4	91.4
92	71.9	72.6	72.7
93	62.8	63.0	62.5
94	65.5	66.4	67.0
95	88.3	90.2	88.5
	Light Work in Week 3 & 4		
96	69.4	70.3	69.2
97	66.0	67.5	68.8
98	69.2	70.9	70.4
99	73.3	73.3	73.7
100	72.9	72.4	73.1
101	60.5	61.3	60.6

TABLE III. 2

PRE PERIOD DATA ON BODY WEIGHTS: EXPERIMENTAL SUBJECTS
(kg)

Groups of Subjects	P I		P II	
	Mean	Range	Mean	Range
Flight 1	65.3	50.6-95.2	65.0	50.3-95.0
Flight 2	66.7	54.1-76.0	66.4	53.9-74.9
Flight 3	65.6	50.4-78.4	65.6	52.0-78.1
Flight 4	62.9	54.2-76.9	62.7	53.5-76.2

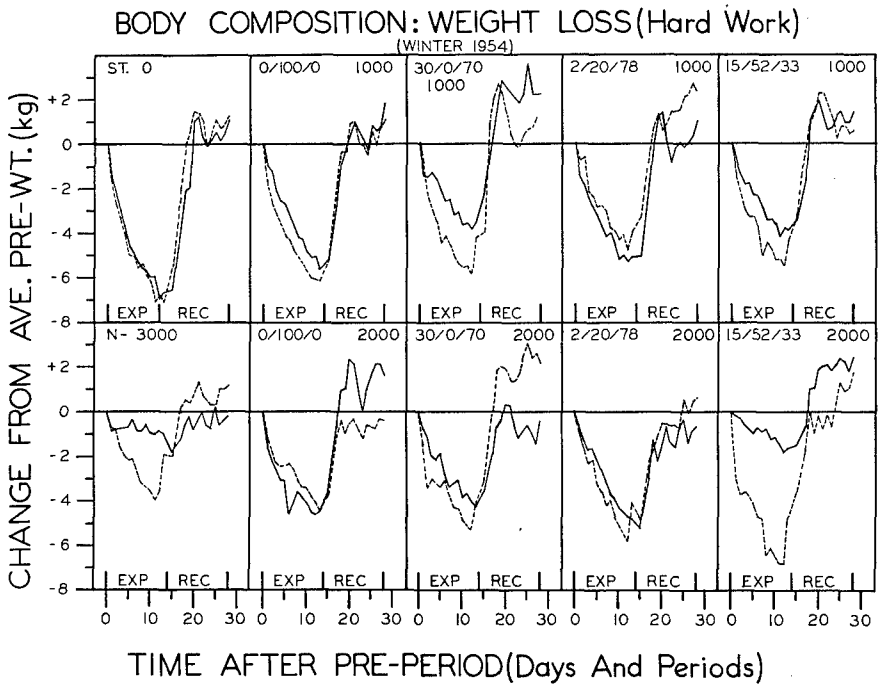


FIGURE III. 2. BODY COMPOSITION: WEIGHT LOSS (HARD WORK), WINTER 1954.

TABLE III. 3

MEAN MAXIMUM WEIGHT LOSS IN FORTY EXPERIMENTAL REGIMENS (kg)

Nutrient Regimen	Light Work		Hard Work	
	U	L	U	L
ST 0	-7.2(2)*	-6.9(2)	-7.2(2)	-7.6(4)
0/100/0 1000	-5.7(2)	-5.1(2)	-5.7(2)	-6.4(2)
0/100/0 2000	-4.4(2)	-3.8(2)	-4.6(1)	-4.5(2)
2/20/78 1000	-4.6(2)	-4.5(2)	-5.7(2)	-4.8(2)
2/20/78 2000	-3.9(3)	-3.9(2)	-4.8(1)	-5.8(2)
15/52/33 1000	-3.4(2)	-3.3(2)	-4.2(1)	-5.7(2)
15/52/33 2000	-3.5(2)	-3.3(2)	-1.8(2)	-6.8(2)
15/52/33 3000	-1.0(2)	-3.1(2)	-1.2(2)	-4.1(2)
30/0/70 1000	-5.9(2)	-5.7(2)	-3.8(2)	-5.9(2)
30/0/70 2000	-2.5(2)	-4.8(2)	-4.3(2)	-5.3(2)

*Numbers in parentheses represent number of subjects.

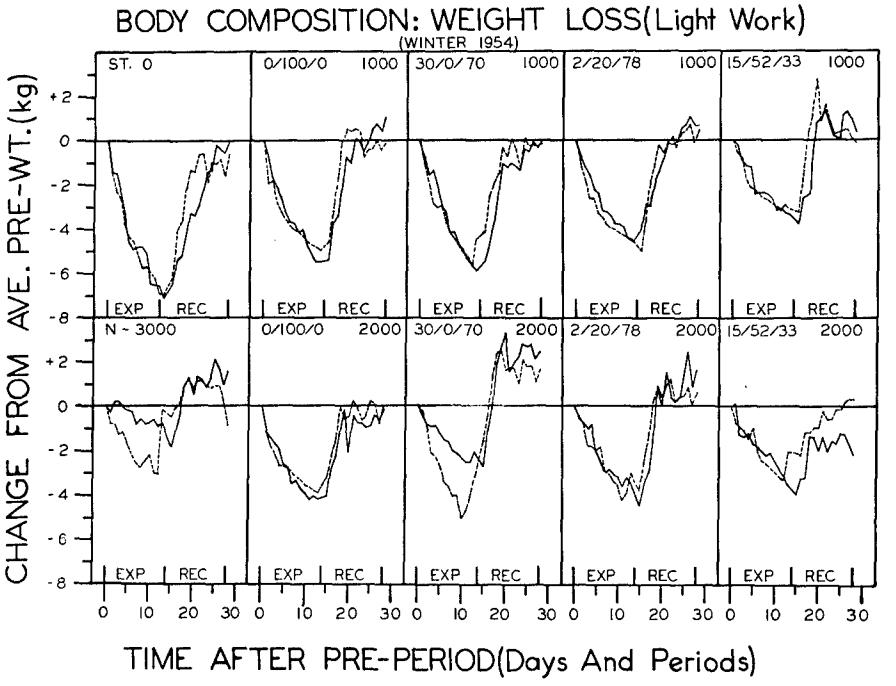


FIGURE III. 3. BODY COMPOSITION: WEIGHT LOSS (LIGHT WORK), WINTER 1954.

2. Body Water

The data from the winter trials will be presented in two sections. The first section will deal with changes in the total body water. The total body water information will be related to the osmotic load of the nutrient mixtures, the work level, and the caloric intake. The second section will deal with a comparison between changes observed in the total body water and water tolerance test given at the close of the experimental period.

Total Body Water. The control data for deuterium oxide space, as estimated from the urinary D_2O/H_2O ratio were obtained late in the pre-period; the experimental data for the deuterium oxide space were obtained after the subjects had subsisted on experimental diets for twelve days. Five subjects were not able to continue the experimental regimen assigned to them. In the case of these men body water estimates were made on the day they came off their diet. In both the control and experimental periods the deuterium oxide was administered by way of an oral dose as described above.

In the 194 tests the average deuterium oxide space was 43.0 liters or 65.5% of the body weight for the control period (Figures III. 4, 5, 6, and 7). In the experimental period, the average deuterium oxide space was 42.3 liters or 69.9%

of the body weight for the unlimited water hard work group; for the limited water hard work group the deuterium oxide space was 37.5 liters or 61.3% of the body weight. The unlimited water light work group had an experimental average of 39.9 liters or 64.3% body weight; and the limited water light work flight had an experimental average of 35.5 liters or 59.8% of the body weight. The range in the control period was 31.7 to 59.5 liters or 56.8 to 72.1% of the body weight. The ranges in the experimental periods were as follows: with limited water light work, 34.9 to 47.0 liters or 60.7 to 69.9% body weight; with unlimited water and hard work, 37.3 to 48.4 liters or 60.4 to 75.5% of body weight; with limited water light work, 33.2 to 38.7 liters or 57.3 to 62.0% of body weight; with limited water hard work, 33.3 to 41.6 liters or 57.1 to 70.2% of body weight.

Inasmuch as osmotic load is important in what follows it is necessary to define the term. As used in this report, the osmotic load of a dietary regimen is defined as the osmotically active material excreted by way of urine and is calculated in microosmols per minute (estimated by the freezing-point method). Osmotic load is conditioned by exogenous intake of inorganic substances and nitrogenous materials; it is also conditioned by endogenous production of osmotically active materials such as ketone bodies, urea, and other organic substances which are excreted in the urine. Thus, the solute load (Table III. 4) represents the total impact of the regimen on the subject during the period of his exposure to nutritional and environmental stress. A very low solute load was imposed by 0/100/0 and a very high one by 30/0/70 2000. Other regimens were intermediate; the rank-order for all regimens is given in the table.

Change in the deuterium oxide space (expressed in liters) will be found in Table III. 5 and Figures III. 4 and 5. So far as the hard work groups are concerned, limitation of water always resulted in a decrease of total body water. The loss of body water was greatest in the lowest (0/100/0 2000 L) and in the highest (30/0/70 2000 L) osmotic load-diets. This result is similar to those obtained with antipyrine (WADC TR 53-484). The explanation offered for this phenomenon is that dehydration resulted in the first case from a pure salt depletion and in the second case from pure water depletion. In the intermediate osmotic loads we may have mixed water and salt depletion dehydration. A third noteworthy observation is the apparent preservation of body water which results from an increase in caloric content in the 2/20/78 and the 15/52/33 diets both with limited and unlimited water.

If we look at the data from another point of view, however, we see that the diets with the greatest osmotic loads (Table III. 4); viz., 30/0/70 2000, 15/52/33 3000, 15/52/33 2000, and 2/20/78 2000, when given with unlimited water, lead to an increase of the absolute amount of body water. The same diets when given with limited water cause a decrease in the total body water in proportion to the magnitude of their osmotic load. With diets in the intermediate or low load range, we observe a decrease in body water in both the unlimited and limited water flights. The absolute loss is always greater with limitation of water than when water is given freely.

In hard work the only exception to the above statements is the 0/100/0 2000 U diet. The results of this experiment are aberrant and we are not able

to explain them on the basis of the above hypothesis. A possible explanation, however, is that with an increased caloric intake there results a decreased necessity for the catabolic destruction of cellular elements and thus body water is maintained along with the tissue saved from destruction by the addition of calories. This explanation might also explain the increase in the body water found in the other 2000-Calorie diets. This question is one that requires further investigation.

Similar variations in total body water occurred in the case of men performing light work: limitation of water always resulted in a decrease in the total body water. There is evidence again of pure salt depletion dehydration in the 0/100/0 1000 both U and L and in the 0/100/0 2000 U diets; and also of pure water depletion dehydration in the 30/0/70 2000 and 2/20/78 2000 diets. The diets with the greatest osmotic loads (30/0/70 2000, 15/52/33 2000, 30/0/70 1000, 15/52/33 2000, and 2/20/78 2000) show again that with water ad libitum the absolute amount of body water is maintained or increased. On the other hand, when water is restricted the loss of body water is proportional to the osmotic load. One striking difference between the light work and hard work flights is that in the 2/20/78 1000 and the 15/52/33 1000 diets, both U and L, there is a greater conservation of body water in the light work group than there is in the hard work groups.

In starvation with free access to water, men doing light work maintain their absolute body water; when water is limited or when forced to work hard a starving man will lose body water. It is of interest to note that the control subjects subsisting on a normal diet with free water experienced an increase in body water if they were associated with a group of men on limited water; if they were associated with a group of men on unlimited water, there occurred no significant change in their body water.

Changes in the deuterium oxide space as expressed in percent of body weight are given in Table III. 6 and Figures III. 6 and 7. In so far as hard work is concerned, limitation of water results in a decrease in the percent water in all but one case, 2/20/78 2000. On this regimen body substance is apparently lost faster than body water. In all of the other instances body water is lost at a faster rate than is body substance.

With free access to water and while the men were working hard, the percent water in the body increased in all cases. This increase seems to bear a relation to the osmotic load of the diet. With high osmotic loads the increase was greater than it was with lower loads. The 0/100/0 2000 U diet again presents an aberrant situation. This diet had the lowest osmotic load of all the diets (Table III. 4) and it is possible that the complications due to salt depletion dehydration upset body water distribution in directions quite different than those of simple water deprivation dehydration.

In the 2/20/78 and 15/52/33 diets at 1000 Calories and limited water, there was evidently a greater percent loss of body water than there was at the 2000-Calorie level. This question came up when we were considering the absolute changes in body water. We decided at the time that there were probably two factors involved: (1) the added calories prevented additional decrease in

cellular mass due to catabolic breakdown and hence maintained that portion of the body water; and (2) the increased osmotic load of the diet was manifested by an increase in body water. The mechanism of the second may be due to solute and water retention, resulting directly from the high osmotic intake.

In the case of flights doing light work, limitation of water resulted in a decrease in the percent body water. In all of these cases body water was lost at a faster rate than was body substance. Free access to water in the light work group did not increase the percent body water in all cases as it did in the hard work group. The exceptions are 0/100/0 1000 U and 30/0/70 2000 U; i.e., the lowest and highest osmotic regimens.

Water Diuresis Test: Pre-Period. The pre-period recoveries range from 45 to 105% (Tables III. 7 and 8; Figures III. 8 and 9). This wide individual variability indicates the need of a pre-period test to make realistic interpretation of the changes in the diuretic response during the experimental periods. These data suggest that a net recovery of less than 50% is probably abnormal.

Water Diuresis Test: Experimental Period. According to the results of this test, there was no significant change in the diuretic response of the control subjects during the course of the six weeks. There was no evidence that work load per se had any effect on the results of the test.

Furthermore total caloric intake was not responsible for any marked changes. On the other hand, water intake and nutrient mixture caused very definite alterations in the diuresis. The most outstanding finding is that the water diuresis test does distinguish state of hydration in the case of high solute load regimens but not in the case of low solute load regimens. For regimens with high osmotic loads there results a low net recovery of the water load, which correlates well with the decreases observed in body water. However, for diets with an intermediate or low osmotic load, the correlation between percent recovery of the water load and the change in body water is not good (Figure III. 10).

Low osmotic loads: The low osmotic load regimens are 0/100/0 1000 and 2000 and 15/52/33 1000. It is evident that, in both the unlimited and limited water groups, the percent water recovered in the experimental water tolerance test was not influenced by a change in body water. With unlimited water there occurs a grouping around 55% recovery of the water load and a near zero change in total body water. The limited water men are also grouped around the 55% recovery and do not manifest the limitation of water imposed upon them by showing a decrease in the percent recovery of the water load. There are a few aberrant points for which we cannot account. With the 15/52/33 1000 regimen the data show very clearly that limitation of water on a low osmotic diet has no effect in changing the percent of recovery of the water tolerance load, even though there does occur a loss of total body water. These changes in total body water are clearly due to pure salt depletion dehydration. The inability on the part of the salt depleted individual, whether on a high or low water level, to retain a water load, we feel, reflects the washing out of solute.

Intermediate osmotic loads: The intermediate osmotic load regimens are

starvation and 2/20/78 1000. In starvation, grouping occurred around 55% recovery of the water load in both the limited and unlimited water flights. The heavy work limited water flight showed a tendency for a higher percent recovery than in the light work group. With 2/20/78 1000 it can be seen that the level of work with unlimited water did not influence the percent recovery of the experimental water load. However, here is the first indication that dehydration and work level do influence this recovery. Men undergoing heavy work and dehydration show an average decrease in body water greater than those undergoing light work and dehydration. If we now consider the percent recovery of the water load in the light of the last observation, it is evident that at this osmotic load a slight increase in dehydration will be manifest by a decrease in the recovered water load.

High osmotic loads: The high osmotic regimens are 30/0/70 1000, 2/20/78 2000, the control subjects' diet (A Ration), 15/52/33 2000, 15/52/33 3000, and 30/0/70 2000. As the osmotic load increased, we observe the following very distinct shifts: In the limited water groups there occurs (1) a decrease in the total body water in proportion to the osmotic load and (2) the percent recovery of the experimental water load decreased in the same manner as did the body water. Thus, there occurred in the unlimited water groups a water tolerance recovery of about 55% during the experimental period and a general increase in total body water. In the limited water groups a drop in the total body water and a shift to the low end of the percent recovery of the water dose is evident.

With the higher osmotic regimens the separation of the unlimited and limited water groups is complete (30/0/70 1000 and 2000). With this nutrient mixture the separation on the basis of the solute load of the diet can be made both with the limited and unlimited water groups. The 30/0/70 1000 diet is ranked in Table III. 4 in fifth place; the 30/0/70 2000 is ranked first. In the case of the 30/0/70 regimen it is at once apparent that hard work did not in itself influence the percent recovery of the water load. Even with unlimited water there was tendency for the subjects subsisting on this diet to become dehydrated. The average decrease in body water with this nutrient mixture and limited water was greatest at the 2000-Calorie level.

According to these results, then, the diuretic response to an oral water load tends to discriminate between a water deficit developing in a man subsisting on a ration low in osmotically active substances and a man on a diet providing relatively large amounts of these substances. The former acts like a normally hydrated man; he does not retain a significant amount of the water load. The latter is different; he retains most of the water load. Speculating, these data suggest that men on 0/100/0 and 2/20/78 had a deficit due to a relatively greater loss of salt than water (tendency to hypotonicity) while the men on the other regimens developed a more nearly pure water deficit (therefore, tendency to hypertonicity).

Water Diuresis Test: Recovery Period. The net recovery tended to return to pre-period values in this phase of the investigation. The values ranged from 41 to 119%. The restoration of normal diuresis was concurrent with restoration of nutrient balances.

Interpretation. The data we have presented clearly show that it is possible accurately to estimate the total body water in man by calculation from the urinary deuterium oxide/hydrogen oxide ratio, and further that the technique of administering the deuterium oxide by way of mouth is also an acceptable one. The simplicity and speed of this method of administering deuterium oxide and collecting samples of body fluid with which the deuterium oxide has equilibrated as compared to intravenous infusion and plasma analysis are very important to those engaged in estimating the body water in man. One of the most important factors yet remaining unfinished in this technique as well as in all other deuterium oxide techniques is the determination of the deuterium oxide lost in the insensible water from the skin and lungs. It was our good fortune to have at hand estimates of insensible loss (WADC TR 53-484); from these we calculated the amount of the administered dose of deuterium oxide lost by way of insensible water. If we were in error in our assumptions, our estimates for the total body water then become relative rather than absolute. The deuterium oxide space determined during the normal pre-periods are comparable to normal values for deuterium oxide space reported by other investigators (Hurst, 1952b; Schloerb et al. 1950; Solomon et al. 1950). Our deuterium oxide space for the experimentally dehydrated, normal young men are the only ones of this sort available. They are slightly greater than the water losses during acute dehydration calculated by Adolph (1947); the reason probably is that the events occurring in chronic dehydration are not comparable to those of acute dehydration.

The results of the water tolerance test demonstrate that it is possible to assess an individual's state of hydration under certain specific conditions. In regard to practical application of this test as a measure of dehydration the following statements can be made: (1) If the recovery of the water load is low, one is justified in stating that water deficiency dehydration is present. (2) If the recovery of the water load is high, then the individual may not be dehydrated at all or he may be undergoing salt deficiency together with dehydration.

It might be possible to distinguish between an individual in a state of normal hydration and one who is undergoing pure salt depletion accompanied by dehydration by a comparison of their osmolar excretion during the four hours following the water load. If the recovery of the water load was high then as stated above either the individual is normally hydrated or is dehydrated and also depleted osmotically. The normal individual will excrete a more concentrated urine than will the salt depleted individual and hence the normally hydrated individual can be detected on the basis of his osmolar excretion in the four-hour pooled urine. If, however, there results from the water diuresis test a high recovery and a low osmolar excretion it is not possible to state definitely whether the results are due to salt depletion together with dehydration or merely a low osmotic intake prior to the test. Further, a single measure of the total body water would not assist in this diagnosis because there is great individual variation in normal body water content. The diagnosis would have to rest on measurements after a period of repletion with respect both to salt and to water; i.e., a therapeutic test.

There are two important clinical conditions which are known to influence

recovery of a water load. These abnormal conditions are adrenal hypofunction and various degrees of renal failure. The physiological basis for their influence on the water tolerance test has been given in another section (vide supra). The interference of renal failure is a real one, since in this malady the kidney is not able to concentrate urine. A water tolerance test, therefore, following a period of negative water or salt balance or following an adequate regimen in one with renal failure, would result in production of urine with almost the same concentration regardless of the preceding regimen. If any doubt exists regarding renal function, the outcome of the water tolerance test should be interpreted with caution. Adrenal hypofunction, we feel, does result in dehydration per se. The water tolerance test (Robinson et al., 1941) which is currently used to test for adrenal hypofunction, we feel, is merely reflecting a mixed salt and water depletion dehydration. The aberrant results occasionally found with uncontrolled Addisonians may be due to fluctuations in salt or water balance.

Why is a water load retained in one dehydrated subject, but not in the other? The possibility that osmotic factors may account for the changes observed in water recovery during the water diuresis test has been investigated. It has been concluded that the following factors, which serve to delimit the osmotic parameters, bear no relation to the percentage recovery in the water diuresis test: (1) minute urine volume, (2) the actual solute load in microosmols/minute, (3) the U/S osmotic ratio and (4) the osmolar concentration in the original urine. However, serum osmotic pressure is the one measurement we have that may correlate with the osmotic concentration of the body as a whole. It did show changes in our subjects (Table III. 9). In the high osmotic load regimens, limited water caused high serum osmotic pressure and was associated with retention of the water dose in the water tolerance test. In starvation no change in water recovery was evident even when the osmotic pressure of the serum was high. Control subjects who were normally hydrated and normally fed at all times had a normal serum osmotic pressure and exhibited no correlation between the high normal osmotic pressure and recovery of the water dose. In the low osmotic load regimens, limitation of water caused no change in serum osmotic pressure, and there was no difference in percentage recovery of the water test dose between the groups on limited water and the groups with unlimited water.

Is it possible that homeostatic mechanisms exist to maintain the total body water and the total osmotic concentration of the body fluids at some constant value? The osmotic pressure of the plasma has been thought to affect osmoreceptors in the central nervous system thus controlling the intake of water; also, it has been shown to affect the production of antidiuretic hormone by the pituitary, thus controlling water excretion by the kidney (Verney et al., 1946, 1948). Homer Smith (1952) emphasized that the volume of the extracellular fluid supplements the osmotic pressure of the plasma in controlling water diuresis. Expansion or contraction of the extracellular fluid compartment may lead, independently of the plasma osmotic pressure, to a decreased or increased secretion of antidiuretic hormone. It is rewarding to investigate the results of the present study theoretically, building on the concepts of Verney and of Smith.

Let:

O = total osmotic content of body fluids
V = total body water

Then:

O/V = C, where C is the assumed normal total body osmotic concentration

In a condition in which water is limited, but a high osmotic load is imposed by the dietary regimen, the situation can be expressed as follows:

$$O/V = O_1 / (V - \Delta V) = C_1$$

where O_1 is the total body osmotic pressure after dehydration and C_1 is the body osmotic concentration after dehydration. In this type of dehydration, water is lost (ΔV) and O remains constant, or is increased by dietary intake and becomes O_1. A water load would cause a diuresis only in so far as it was greater than ΔV or would cause $O_1 / (V-\Delta V)$ to decrease below C. Since V is the limiting quantity, added water would be retained under the conditions of our experiment, in which the water test dose was less than ΔV.

We have experimental evidence to support this portion of the hypothesis. In dietary regimens in which high osmotic loads (high protein, high inorganic salt) were imposed together with limitation of water, the osmotic pressure of the serum increased, the volume of the total body water decreased (Figure III. 11), and the osmotic content of the body presumably remained constant or increased because of the diet (Figure III. 12). In this situation, water in the water tolerance test was retained.

When dehydration is provoked by the limitation of water during regimens of low osmotic load (e.g., in the pure carbohydrate regimen) the situation can be expressed as follows:

$$O/V = (O-\Delta O) / (V-\Delta V) = C_2$$

where C_2 is the total body osmotic concentration after dehydration. In this kind of dehydration both O and V decrease, O because the diet is low in salt and protein and V because of water restriction. Therefore, C_2 depends upon the relative magnitude of ΔO and ΔV. If after dehydration C_2 were equal to or less than C, an increase in the denominator by addition of water would result in the excretion of the added water to reduce the ratio $(O-\Delta O) / (V - \Delta V)$ in an attempt to protect C.

We have experimental evidence to support this portion of the hypothesis. In the regimens of low osmotic load during limitation of water, the osmotic pressure of the serum remained unchanged (Figure III. 11), the volume of the total body water decreased, and the osmotic content of the body presumably also decreased (Figure III. 12). In the water tolerance test water was not retained.

The above theoretical treatment is consistent with all of the phenomena observed during the water diuresis tests in the present study.

TABLE III. 4

RELATIVE OSMOTIC LOAD OF DIFFERENT REGIMENS
(Mean of Exp I and Exp II, U and L, All Subjects)

Experimental Regimen	Mean Osmotic Load (μ-osmols*/min)	Relative Rank-Order
ST 0	465	8
0/100/0 1000	257	10
0/100/0 2000	219	11
2/20/78 1000	497	7
2/20/78 2000	626	6
15/52/33 1000	418	9
15/52/33 2000	780	4
15/52/33 3000	865	2
30/0/70 1000	732	5
30/0/70 2000	1074	1
Control	825	3

* μ-osmols means microosmols excreted during a two-hour period.

TABLE III. 5

BODY WATER: D_2O SPACE IN LITERS

Experimental Regimen		Hard Work			Light Work		
		Pre	Exp	Δ	Pre	Exp	Δ
ST 0	U	43.7	40.1	-3.6	41.4	42.0	+0.6
	L	45.7	37.0	-8.7	44.1	34.1	-10.0
0/100/0	U	41.5	38.5	-3.0	38.1	32.1	-6.0
1000	L	42.5	37.7	-4.8	44.7	34.7	-10.0
0/100/0	U	47.2	47.3	+0.1	40.5	38.4	-2.1
2000	L	40.3	33.7	-6.6	44.7	38.7	-6.0
2/20/78	U	47.3	45.3	-2.0	39.6	38.5	-1.1
1000	L	41.9	36.5	-5.4	41.3	36.9	-4.4
2/20/78	U	43.2	44.3	+1.1	46.9	47.7	+0.8
2000	L	44.3	41.6	-2.7	44.9	35.4	-9.5
15/52/33	U	40.3	38.7	-1.6	37.5	37.6	+0.1
1000	L	41.1	34.7	-6.4	38.1	33.2	-4.9
15/52/33	U	39.7	40.6	+0.9	43.7	44.7	+1.0
2000	L	42.5	38.1	-4.4	38.3	34.0	-4.3
15/52/33	U	42.2	42.8	+0.6	42.8	43.8	+1.0
3000	L	46.3	41.4	-4.9	42.9	36.5	-6.4
30/0/70	U	38.2	37.3	-0.9	40.4	39.2	-1.2
1000	L	45.5	41.1	-4.4	41.8	35.6	-6.2
30/0/70	U	45.2	48.4	+3.2	37.4	34.9	-2.5
2000	L	42.5	33.3	-9.2	38.3	30.9	-7.4
Control	U	46.3	47.3	+1.0	41.8	42.0	+0.2
	L	41.3	43.8	+2.5	42.9	45.4	+2.5

TABLE III. 6

BODY WATER: D_2O SPACE: % BODY WEIGHT

Experimental Regimen		Hard Work			Light Work		
		Pre	Exp	Δ	Pre	Exp	Δ
ST 0	U	67.5	67.8	+0.3	61.2	67.4	+6.2
	L	66.5	59.8	-6.7	66.9	51.1	-9.8
0/100/0	U	67.7	68.7	+1.0	63.4	58.3	-5.1
1000	L	63.0	61.1	-1.9	71.9	59.9	-12.0
0/100/0	U	66.0	70.9	+4.9	62.3	62.9	+0.6
2000	L	67.6	60.1	-7.5	66.0	59.8	-6.2
2/20/78	U	67.4	70.7	+3.3	62.7	64.5	+1.8
1000	L	68.7	64.2	-4.3	66.0	62.9	-3.1
2/20/78	U	65.8	70.9	+5.1	65.0	69.9	+4.9
2000	L	61.3	62.3	+1.0	68.4	57.3	-11.1
15/52/33	U	66.1	67.5	+1.4	64.8	69.2	+4.4
1000	L	60.7	55.9	-4.8	65.8	60.6	-5.2
15/52/33	U	63.9	66.8	+2.9	57.8	61.2	+3.4
2000	L	57.2	57.1	-0.1	63.2	59.3	-3.9
15/52/33	U	65.7	67.5	+1.8	63.9	65.8	+1.9
3000	L	66.7	62.9	-3.8	67.8	59.7	-8.1
30/0/70	U	72.1	75.5	+3.4	59.9	62.1	+2.2
1000	L	71.0	70.2	-0.8	65.9	60.9	-5.0
30/0/70	U	56.8	62.5	+5.7	62.4	60.7	-1.7
2000	L	68.5	59.1	-9.4	68.9	60.0	-8.9
Control	U	58.8	60.4	+2.4	60.0	60.6	+0.6
	L	57.4	60.1	+2.7	62.0	66.2	+4.2

TABLE III. 7

WATER DIURESIS TEST AND TOTAL BODY WATER: HARD WORK

Experimental Regimen		Sub-ject	Water Diuresis (% Recovery)			Body Water (Liters)		
			Pre	Exp	Δ	Pre	Exp	Δ
ST 0	U	1	50	58	+8	----	----	----
		3	69	31	-53	46.3	45.5	-0.8
		2	63	62	-1	41.2	34.7	-6.5
		4	59	57	-2	----	----	----
	L	23	121	82	-39	45.4	36.5	-8.9
		25	86	71	-15	47.4	36.3	-11.1
		24	115	52	-63	39.8	37.4	-2.4
		26	100	57	-43	50.0	37.8	-12.2
0/100/0	U	5	92	86	-6	46.1	43.5	-2.6
1000		6	79	46	-33	37.0	33.4	-3.6
	L	27	86	48	-38	44.4	41.4	-3.3
		28	100	61	-39	40.7	34.2	-6.5
0/100/0	U	7	81	65	-16	47.2	47.3	+0.1
2000		8	--	--	--	----	----	----
	L	29	45	63	+18	41.4	34.7	-6.7
		30	74	67	-7	39.3	32.7	-6.6

TABLE III. 7 (Contd)

Experimental Regimen		Subject	Water Diuresis (% Recovery)			Body Water (Liters)		
			Pre	Exp	Δ	Pre	Exp	Δ
2/20/78	U	13	70	76	+6	48.1	46.0	-2.1
1000		14	64	88	+24	46.5	44.6	-1.9
	L	35	68	51	-17	41.4	35.6	-5.8
		36	21	21	0	42.5	37.3	-5.2
2/20/78	U	15	75	52	-23	48.3	48.3	0.0
2000		16	63	105	+42	38.1	40.2	+2.1
	L	37	80	40	-40	42.2	44.0	+1.8
		38	37	0	-37	46.4	39.2	-7.2
15/52/33	U	17	70	59	-11	44.8	43.9	-0.9
1000		18	75	68	-7	35.8	33.5	-2.3
	L	39	68	1	-67	40.7	31.3	-9.4
		40	73	30	-43	41.4	38.1	-3.3
15/52/33	U	19	75	69	-6	40.6	42.5	+1.9
2000		20	93	61	-32	38.7	38.7	0.0
	L	41	55	0	-55	42.5	38.1	-4.4
		42	--	--	--	----	----	----
15/52/33	U	21	117	57	-60	39.1	41.5	+2.5
3000		22	76	84	+8	45.3	44.0	-1.3
	L	43	94	3	-91	43.2	38.7	-4.5
		44	69	30	-39	49.4	44.1	-5.3
30/0/70	U	9	93	59	-34	35.5	34.6	-0.9
1000		10	73	60	-13	40.9	40.1	-0.8
	L	31	87	0	-87	46.4	41.9	-4.5
		32	60	3	-57	44.7	40.2	-4.5
30/0/70	U	11	76	68	-8	45.9	44.4	-1.5
2000		12	82	70	-12	44.5	52.4	+7.9
	L	33	77	3	-74	37.0	30.8	-6.2
		34	58	17	-41	48.1	35.8	-12.3
Control	U	90	79	28	-51	44.1	44.5	+0.4
		91	77	80	+3	49.6	51.9	+2.3
		92	114	95	-19	45.2	45.7	+0.5
	L	93	64	93	+29	35.8	38.8	+3.0
		94	46	88	+42	59.5	59.1	-0.4
		95	73	68	-5	49.3	53.2	+3.9

TABLE III. 8

WATER DIURESIS TEST AND TOTAL BODY WATER: LIGHT WORK

Experimental Regimen		Subject	Water Diuresis (% Recovery)			Body Water (Liters)		
			Pre	Exp	Δ	Pre	Exp	Δ
ST 0	U	45	75	66	-9	44.3	47.5	+3.2
		46	96	55	-41	38.5	38.3	-0.2
		47	92	47	-35	41.6	40.2	-1.4
	L	68	59	60	+1	42.2	32.0	-10.2
		69	97	31	-66	48.8	36.3	-12.5
		70	42	50	+8	41.3	34.0	-7.3
0/100/0	U	49	110	67	-43	37.0	30.3	-6.7
1000		50	87	34	-53	39.2	34.0	-5.2
	L	71	56	12	-44	44.5	36.6	-7.9
		72	57	75	+18	44.8	32.7	-12.1
0/100/0	U	51	99	22	-77	42.9	38.8	-4.1
2000		52	90	47	-43	38.2	37.9	-0.3
	L	73	55	75	+20	40.1	33.8	-6.3
		74	58	55	-3	49.3	43.6	-5.7
2/20/78	U	57	78	72	-6	45.0	43.1	-1.9
1000		58	--	--	--	34.2	33.9	-0.3
	L	79	50	83	+33	42.1	34.3	-7.8
		80	43	86	+43	40.4	39.6	-0.8
2/20/78	U	59	93	75	-18	49.5	47.8	+0.3
2000		60	77	58	-19	44.3	45.5	+1.2
		61	--	--	--	----	----	----
	L	81	78	30	-48	44.3	35.8	-8.5
		82	61	7	-54	45.4	35.0	-10.4
15/52/33	U	48	60	64	-4	43.4	41.6	-1.8
1000		62	93	52	-41	31.7	33.5	+1.8
	L	83	57	82	+25	36.8	30.4	-6.4
		84	103	50	-53	39.4	36.0	-3.4
15/52/33	U	63	86	47	-39	37.9	39.1	+1.2
2000		64	98	63	-35	49.5	50.3	+0.8
	L	85	79	0	-79	40.9	34.0	-6.9
		86	89	1	-88	35.8	34.0	-1.8
15/52/33	U	65	47	81	+34	41.2	40.1	-1.1
3000		66	61	53	-8	44.4	47.5	+3.1
	L	87	96	0	-96	43.6	36.9	-6.7
		88	77	1	-76	42.3	36.1	-6.2
30/0/70	U	53	88	55	-33	42.5	40.5	-2.0
1000		54	76	75	-1	38.4	37.9	-0.5
	L	75	50	3	-47	43.8	36.2	-7.6
		76	78	5	-73	39.9	35.0	-4.9
30/0/70	U	55	85	73	-12	35.9	35.3	-0.6
2000		56	106	64	-42	38.9	34.4	-4.5
	L	77	68	6	-62	37.9	30.5	-7.4
		78	72	2	-70	38.6	31.4	-7.2
Control	U	96	72	65	-7	44.6	43.2	-1.4
		97	54	54	0	39.0	37.2	-1.8
		98	99	74	-25	41.9	45.7	+3.8
	L	99	49	87	+38	45.5	48.0	+2.5
		100	--	--	--	43.1	44.3	+1.2
		101	64	72	+8	40.1	44.0	+3.9

TABLE III. 9

MEAN SERUM OSMOTIC CONCENTRATION

Regimen		Subjects (number)	Observations (number)	Serum Osmotic Pressure (milliosmols/liter)
Starvation	U	6	10	296
Starvation	L	7	14	309
Pure CHO	U	8	16	305
Pure CHO	L	8	16	308
High solute load	U	8	16	308
High solute load	L	8	16	333
Controls	U	12	24	308

FIGURE III. 4. BODY WATER I. D_2O SPACE (LITERS, HARD WORK). WINTER 1954.

FIGURE III. 5. BODY WATER II. D_2O SPACE (LITERS, LIGHT WORK). WINTER 1954.

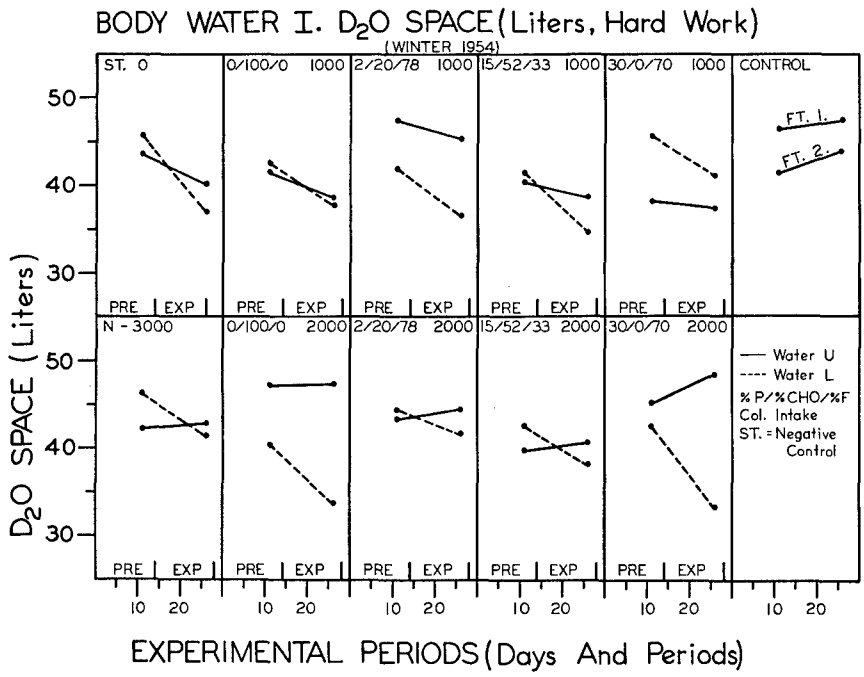


FIGURE III. 4

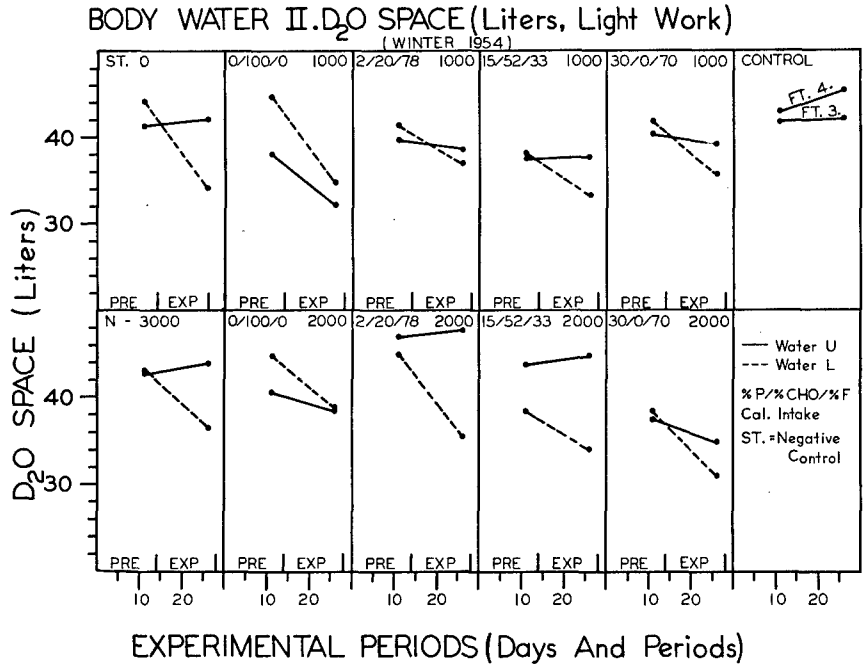
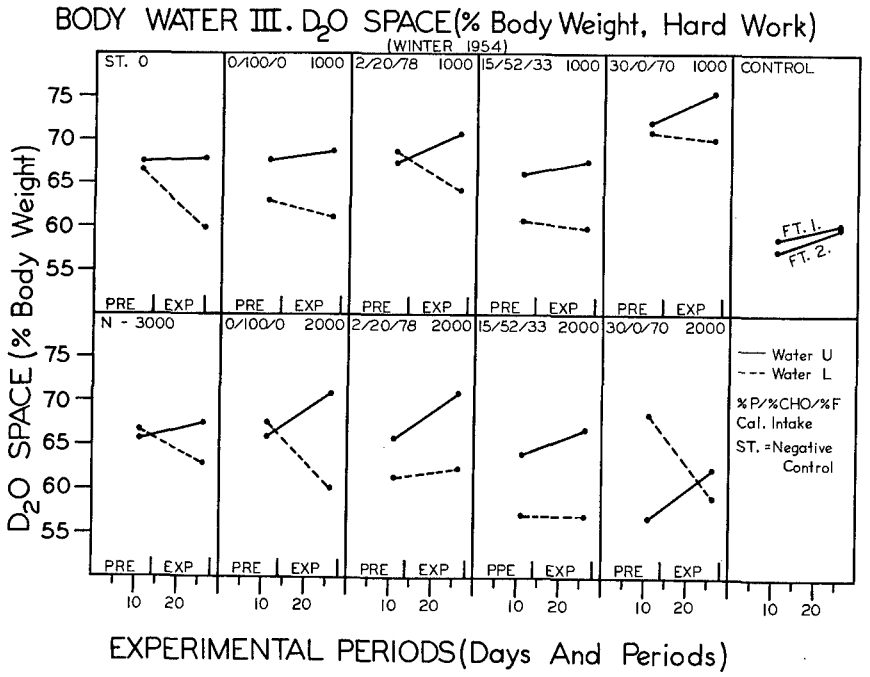


FIGURE III. 5

FIGURE III. 6. BODY WATER III. D_2O SPACE (% BODY WEIGHT, HARD WORK). WINTER 1954.

FIGURE III. 7. BODY WATER IV. D_2O SPACE (% BODY WEIGHT, LIGHT WORK). WINTER 1954.


BODY WATER III. D_2O SPACE (% Body Weight, Hard Work)
(WINTER 1954)
ST. 0
0/100/0 1000
2/20/78 1000
15/52/33 1000
30/0/70 1000
CONTROL
N - 3000
0/100/0 2000
2/20/78 2000
15/52/33 2000
30/0/70 2000
PRE EXP
PPE EXP
FT. 1.
FT. 2.
Water U
Water L
%P/%CHO/%F
Cal. Intake
ST. =Negative Control
D_2O SPACE (% Body Weight)
75
70
65
60
55
10 20
EXPERIMENTAL PERIODS (Days And Periods)

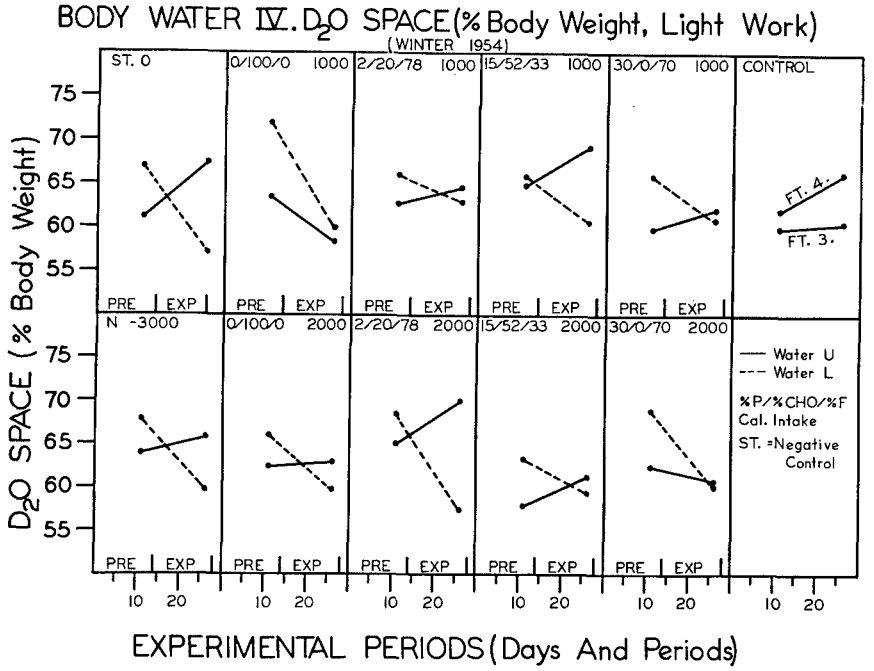

BODY WATER IV. D_2O SPACE (% Body Weight, Light Work)
(WINTER 1954)
ST. 0
0/100/0 1000
2/20/78 1000
15/52/33 1000
30/0/70 1000
CONTROL
N -3000
0/100/0 2000
2/20/78 2000
15/52/33 2000
30/0/70 2000
PRE EXP
FT. 4.
FT. 3.
Water U
Water L
%P/%CHO/%F
Cal. Intake
ST. =Negative Control
D_2O SPACE (% Body Weight)
75
70
65
60
55
10 20
EXPERIMENTAL PERIODS (Days And Periods)

FIGURE III. 7

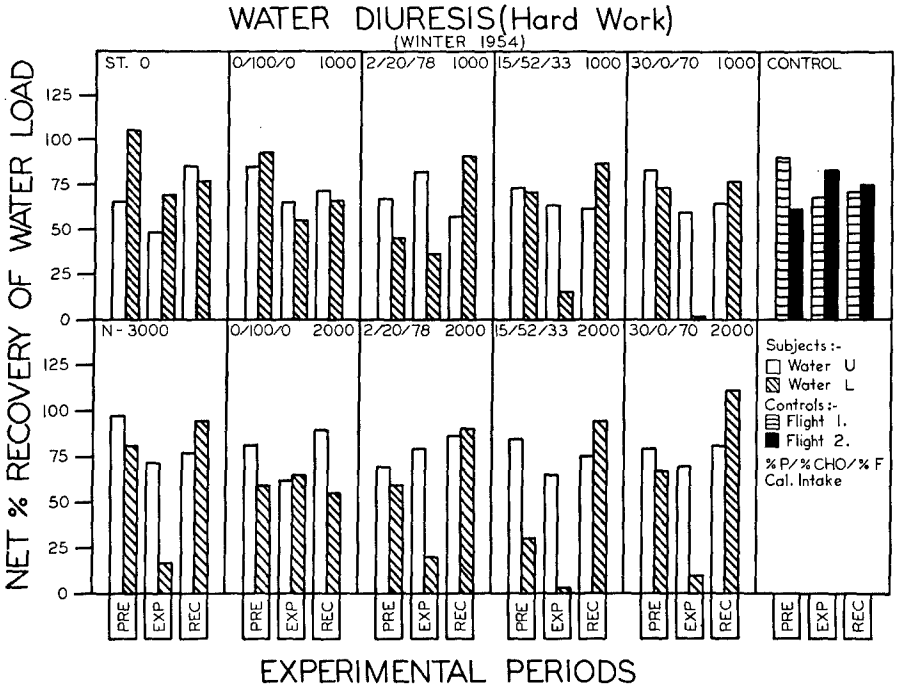


FIGURE III. 8. WATER DIURESIS (HARD WORK). WINTER 1954.

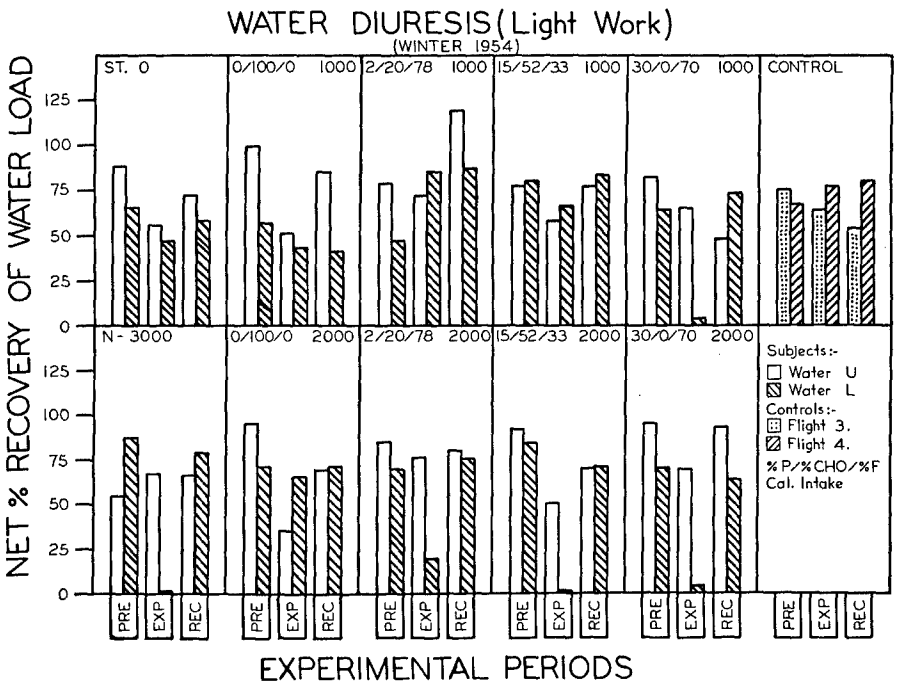


FIGURE III. 9. WATER DIURESIS (LIGHT WORK). WINTER 1954.

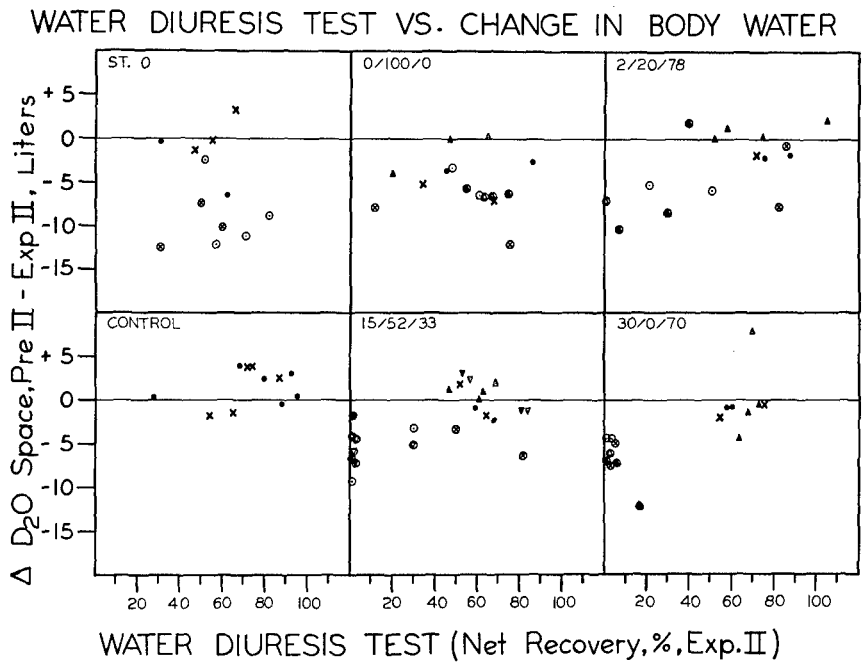


FIGURE III. 10

FIGURE III. 10. WATER DIURESIS TEST VS. CHANGE IN BODY WATER.

Key

ST 0 and Controls
Dots: Hard Work
Crosses: Light Work
Circles: Limitation of Water

Other Regimens
Circles: Limitation of Water
Dots: 1000 Cal., Hard Work
Crosses: 1000 Cal., Light Work
Open Triangles: 2000 Cal., Hard Work
Solid Triangles: 2000 Cal., Light Work
Reversed Open Triangles: 3000 Cal., Hard Work
Reversed Solid Triangles: 3000 Cal., Light Work

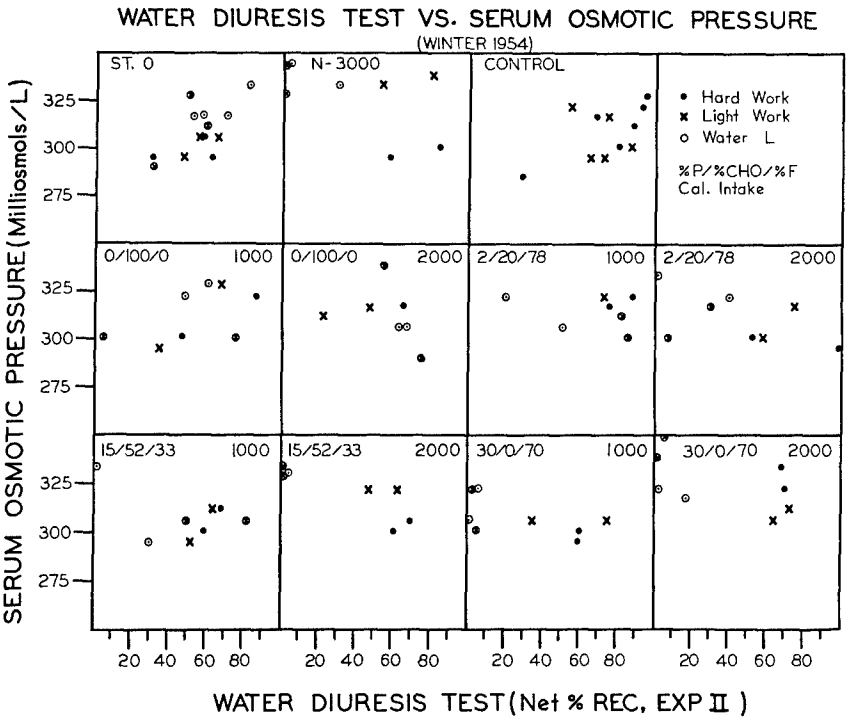


FIGURE III. 11. WATER DIURESIS TEST VS. SERUM OSMOTIC PRESSURE, WINTER 1954.

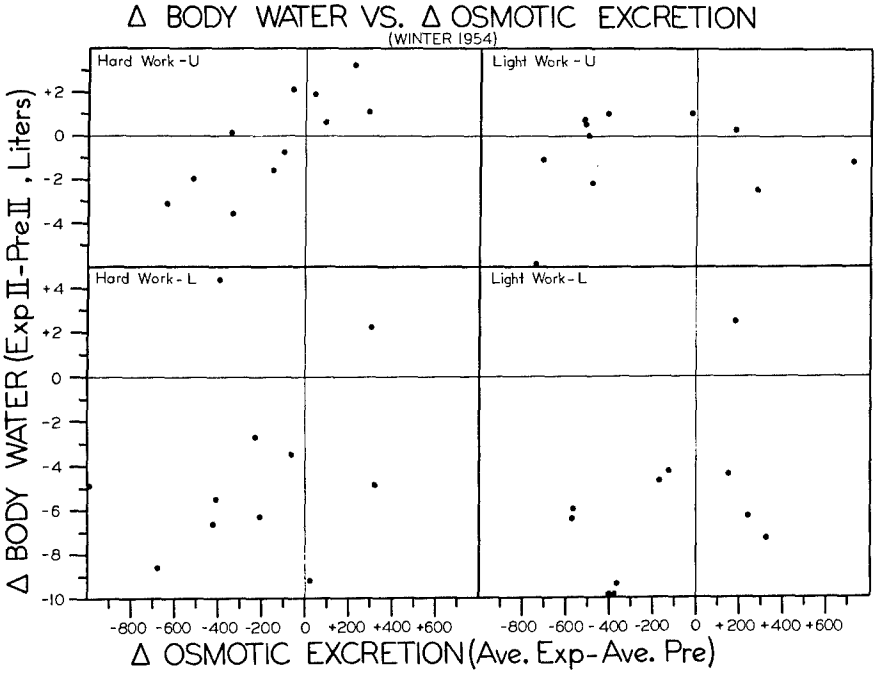


FIGURE III. 12. Δ BODY WATER VS. Δ OSMOTIC EXCRETION, WINTER 1954.

3. Body Fat

Body fat was estimated from measurements of skinfold thickness with Minnesota calipers (Sargent et al., 1953). The pre-period data for the five groups of subjects are summarized in Table III. 10. The values agree closely with those obtained on the students in 1953. Attention is directed to three points: (1) The flight leaders, an older group, had more body fat (both relative and absolute) than did the volunteer airmen. (2) The inter-group differences are much less in P II than in P I. (3) Flight 4 had the least body fat in both weeks of the pre-period. Since all subjects in this flight were Negroes, it was possible that a racial difference in body composition might account for the lower values in Flight 4. Accordingly the four flights were divided into two groups - white and non-white (Negroes). The mean values for kg of body fat were calculated for the eight groups. No significant differences between the white and Negro subjects was evident (Table III. 11). The high value of 4.7 kg for the white subjects of Flight 1 was due to the one obese individual in that group. When his data were excluded from the calculation, the mean became 3.2 kg. Although the colored subjects tended to have lower values for body fat, we may conclude that the means for Flight 4 represent individual differences rather than racial differences.

The paired means for fat content of the body during the three phases of the study are given in Tables III. 12 and 13. The percentage of body fat lost during the experimental weeks was calculated and the results are summarized in Table III. 14. Several interesting points are brought out in a study of that table. (1) All four of the groups of controls gained body fat. (2) Among the volunteer subjects more fat was lost by those doing hard work than those doing light work. The three exceptions were ST 0 U, 30/0/70 U, and 15/52/33 3000 L. (3) In general, there was a closer parallelism between the U and L groups than reported in 1953. These data do not substantiate the observation made by Sargent (1954) that dehydration decreases the apparent loss of body fat. If anything, the losses tended to be greater among the L groups than among the U. The only explanation which can be offered for this disagreement is that in 1953 all skinfold measurements were made by one observer while in 1954 four different observers made the measurements. The larger number of observers may have increased the variability of the data so as to obliterate the trend reported earlier. (4) No striking correlation exists between caloric intake and loss of body fat. Grossman and Sloane (1954) have recently reported an inverse relation between caloric intake and percent body fat. (5) The distribution of calories was not correlated with differences in amount of fat lost. (6) The overall impression one derives from these data is the mere exposure to an experiment regimen caused a loss of body fat. Food was certainly the dominant element, for the control subjects were exposed to the same environmental conditions and the same amount of work and they gained body fat. Work modified the response, for the hard work groups lost more fat than the light work ones.

The loss of body fat tended to be corrected in REC I (Tables III. 12 and 13). In REC II there was a strong trend to laying down relatively more fat than had been present in the pre-periods.

We do not believe that the present data on body fat are very meaningful. In our opinion, after two years of extensive experience, this technic is not suitable for routine clinical examination.

TABLE III. 10

PRE-PERIOD DATA ON BODY FAT

Groups of Subjects	P I Mean	P I Range	P II Mean	P II Range
		Per Cent Body Fat		
Flight 1	5.7	2.6-28.1	5.5	2.6-24.5
Flight 2	5.6	3.9-8.8	5.5	3.4-9.6
Flight 3	4.3	1.7-7.2	5.5	3.4-12.3
Flight 4	3.6	2.3-4.1	4.8	2.7-9.0
Controls	7.4	3.7-13.6	8.0	3.5-16.9
		Kg Body Fat		
Flight 1	4.1	1.3-26.8	3.8	1.3-23.0
Flight 2	3.8	2.3-6.2	3.6	2.4-6.9
Flight 3	2.8	1.0-4.6	3.7	1.8-9.0
Flight 4	2.3	1.7-3.7	2.9	1.5-5.5
Controls	5.6	2.3-12.5	6.1	2.4-15.5

TABLE III. 11

RACE VS. KILOGRAMS BODY FAT
(Means for PI and PII)

Groups of Subjects	White Mean	White Range	Negro Mean	Negro Range
Flight 1	4.7*	1.3-26.8	2.5	1.5-4.1
Flight 2	4.0	2.5-6.9	3.6	2.3-5.9
Flight 3	3.3	1.0-5.9	3.0	1.6-5.0
Flight 4	No Subjects		2.6	2.3-9.0

*Mean equals 3.2 kg with obese subject (No. 12) excluded.

TABLE III. 12

BODY COMPOSITION: PER CENT BODY FAT

Experimental Regimen		Hard Work					Light Work				
		Pre*	Exp		Rec		Pre*	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	4.5	4.1	3.0	4.4	5.0	6.0	4.1	4.0	4.7	6.9
	L	6.7	5.3	4.4	5.4	5.9	3.8	3.7	3.2	3.6	4.5
0/100/0	U	5.0	3.8	3.1	4.2	4.4	3.4	3.2	4.2	4.0	6.0
1000	L	7.0	6.7	3.6	6.8	5.1	3.4	3.6	3.5	3.8	4.2
0/100/0	U	5.3	6.7	5.3	5.6	6.2	4.0	3.7	4.2	4.3	4.6
2000	L	4.9	4.0	3.6	4.1	4.0	4.0	4.2	3.9	4.8	5.0
2/20/78	U	4.2	3.6	3.9	3.6	4.6	4.6	5.2	4.4	4.6	5.3
1000	L	4.0	4.2	3.2	4.6	4.0	4.5	4.6	4.2	4.4	4.9
2/20/78	U	5.6	5.8	4.6	5.5	6.6	6.1	6.2	4.8	6.2	8.0
2000	L	5.8	5.0	4.6	4.8	4.6	4.1	3.9	4.0	4.2	5.0
15/52/33	U	4.5	4.2	3.8	3.8	4.8	3.3	3.6	2.8	4.1	6.2
1000	L	6.3	5.6	4.9	6.4	5.0	4.0	4.2	3.3	3.7	4.0
15/52/33	U	4.3	3.9	3.4	4.0	5.2	6.3	7.8	4.9	6.4	7.1
2000	L	5.9	4.4	3.6	5.6	5.0	4.3	4.2	5.0	3.4	4.6
15/52/33	U	5.5	5.8	6.1	3.8	5.8	4.4	4.4	4.8	4.6	6.3
3000	L	5.3	4.4	4.8	5.1	4.9	5.3	4.8	4.1	4.0	5.0
30/0/70	U	3.0	2.9	2.5	3.2	4.0	6.1	7.3	5.8	6.8	8.3
1000	L	4.3	3.6	4.4	4.4	3.9	4.6	3.8	3.6	3.6	4.6
30/0/70	U	15.2	15.4	15.8	16.5	15.4	4.6	4.3	4.4	4.9	5.9
2000	L	4.6	3.5	4.1	4.8	5.0	3.7	3.8	3.7	3.8	4.4
Control	U	8.7	9.5	11.1	10.6	13.1	4.0	4.1	4.2	4.0	4.6
	L	8.8	11.0	9.0	12.8	7.5	9.3	11.2	10.7	7.6	9.0

*Mean values for PI and PII.

TABLE III. 13

BODY COMPOSITION: KILOGRAMS BODY FAT

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	2.8	2.6	1.8	2.8	3.2	4.0	2.6	2.6	3.2	4.8
	L	4.5	3.4	2.7	3.7	4.2	2.4	2.2	1.9	2.3	3.0
0/100/0	U	3.1	2.3	1.8	2.6	2.8	2.1	1.8	2.3	2.4	3.7
1000	L	4.8	4.3	2.2	4.6	3.4	2.1	2.0	2.0	2.4	2.6
0/100/0	U	4.0	4.9	3.8	4.2	4.8	2.6	2.3	2.6	2.8	3.0
2000	L	2.9	2.2	2.0	2.4	2.4	2.8	2.7	2.6	3.2	3.5
2/20/78	U	3.0	2.4	2.5	2.5	3.2	2.9	3.2	2.6	2.8	3.4
1000	L	2.4	2.5	1.8	2.8	2.6	2.8	2.7	2.5	2.8	3.1
2/20/78	U	3.6	3.6	2.8	3.6	4.2	4.3	4.3	3.2	4.2	5.7
2000	L	4.2	3.4	3.1	3.4	3.3	2.7	2.5	2.4	2.8	3.4
15/52/33	U	2.8	2.4	2.2	2.4	3.0	1.9	2.0	1.6	2.4	3.7
1000	L	4.1	3.6	3.1	4.4	3.4	2.3	2.3	1.8	2.2	2.3
15/52/33	U	2.6	2.4	2.0	2.6	3.4	4.7	5.6	3.5	4.6	5.2
2000	L	4.2	3.0	2.3	4.1	3.6	2.8	2.7	3.0	2.1	3.0
15/52/33	U	3.6	3.9	4.0	2.5	3.8	3.0	3.0	3.2	3.1	4.4
3000	L	3.6	3.0	3.1	3.6	3.4	3.3	2.7	2.4	2.6	3.2
30/0/70	U	1.6	1.5	1.2	1.8	2.2	4.2	4.8	3.6	4.6	5.6
1000	L	2.8	2.2	2.6	3.0	2.5	2.9	2.3	2.2	2.2	3.0
30/0/70	U	13.9	13.6	13.8	14.6	13.6	2.7	2.5	2.6	3.0	3.6
2000	L	2.8	2.0	2.2	3.0	3.2	2.1	2.0	1.9	2.2	2.5
Control	U	7.3	8.2	9.3	9.0	10.9	2.9	2.9	2.9	2.8	3.2
	L	6.6	8.5	6.8	9.8	5.7	6.7	8.0	7.4	5.4	6.1

*Mean values for PI and PII.

TABLE III. 14

PER CENT LOSS OF BODY FAT*

Experimental Regimen		Hard Work U	Hard Work L	Light Work U	Light Work L
ST 0		39.4	36.7	46.6	25.2
0/100/0	1000	44.4	52.8	-13.4	4.8
2/20/78	1000	15.6	24.1	11.1	10.0
15/52/33	1000	21.9	26.0	18.0	21.2
30/0/70	1000	15.6	4.4	14.1	27.4
0/100/0	2000	19.0	30.8	4.0	10.1
2/20/78	2000	22.2	24.4	21.2	11.7
15/52/33	2000	20.1	46.2	35.1	-12.0
30/0/70	2000	15.2	19.6	5.2	7.2
15/52/33	3000	-2.7	14.0	-11.2	29.5
Control		-30.0	-1.6	-6.1	-10.3

* $100 \frac{\text{(Body Fat, kg in PI \& II - Body Fat, kg in Exp II)}}{\text{(Body Fat, kg in PI \& PII)}}$

4. Photographic Records of Subjects' Bodies

Two photographs (a front view and a side view) were made of each of the 87 subjects during the pre-period and on the day that the experimental regimen terminated. Their purpose was to illustrate gross changes in external appearance of the body that might have occurred as a result of the experimental regimens. Such changes were better brought out photographically than description in words. Selection of these photographs for presentation in this report was made by choosing one subject in each nutrient regimen in each of two flights, that performing hard work with limited water (Flight 2) and that performing light work with unlimited water (Flight 3). These two flights represented the extremes of water and work which might be experienced by the castaway.

Hard work together with limitation of water resulted in visible changes in 0, 1000, and 2000-Calorie regimens (Figures III. 13 and 14). Even the subject on 3000 Cal/day in this group showed changes attributable to dehydration and not calorie deficiency. In contrast, unlimited water and light work resulted in less marked gross changes even in starvation (Figures III. 15 and 16). Some of the 2000-Calorie regimens and the 3000-Calorie regimen in this group produced minimal changes, if any.

Subjects in Flight 1 (hard work, unlimited water) and Flight 4 (light work, limited water) developed physical changes intermediate between those exhibited by the corresponding subjects in Flights 2 and 3.

FIGURE III. 13. SUBJECTS OF FLIGHT 2 BEFORE AND AFTER EXPERIMENTAL PERIODS (STARVATION AND 1000 CALORIES, LIMITED WATER, HARD WORK).

A. SUBJECT 23: PRE

B. SUBJECT 23: ST O L

C. SUBJECT 27: PRE

D. SUBJECT 27: 0/100/0 1000 L

E. SUBJECT 31: PRE

F. SUBJECT 31: 30/0/70 1000 L

G. SUBJECT 36: PRE

H. SUBJECT 36: 2/20/78 1000 L

I. SUBJECT 40: PRE

J. SUBJECT 40: 15/52/33 1000 L

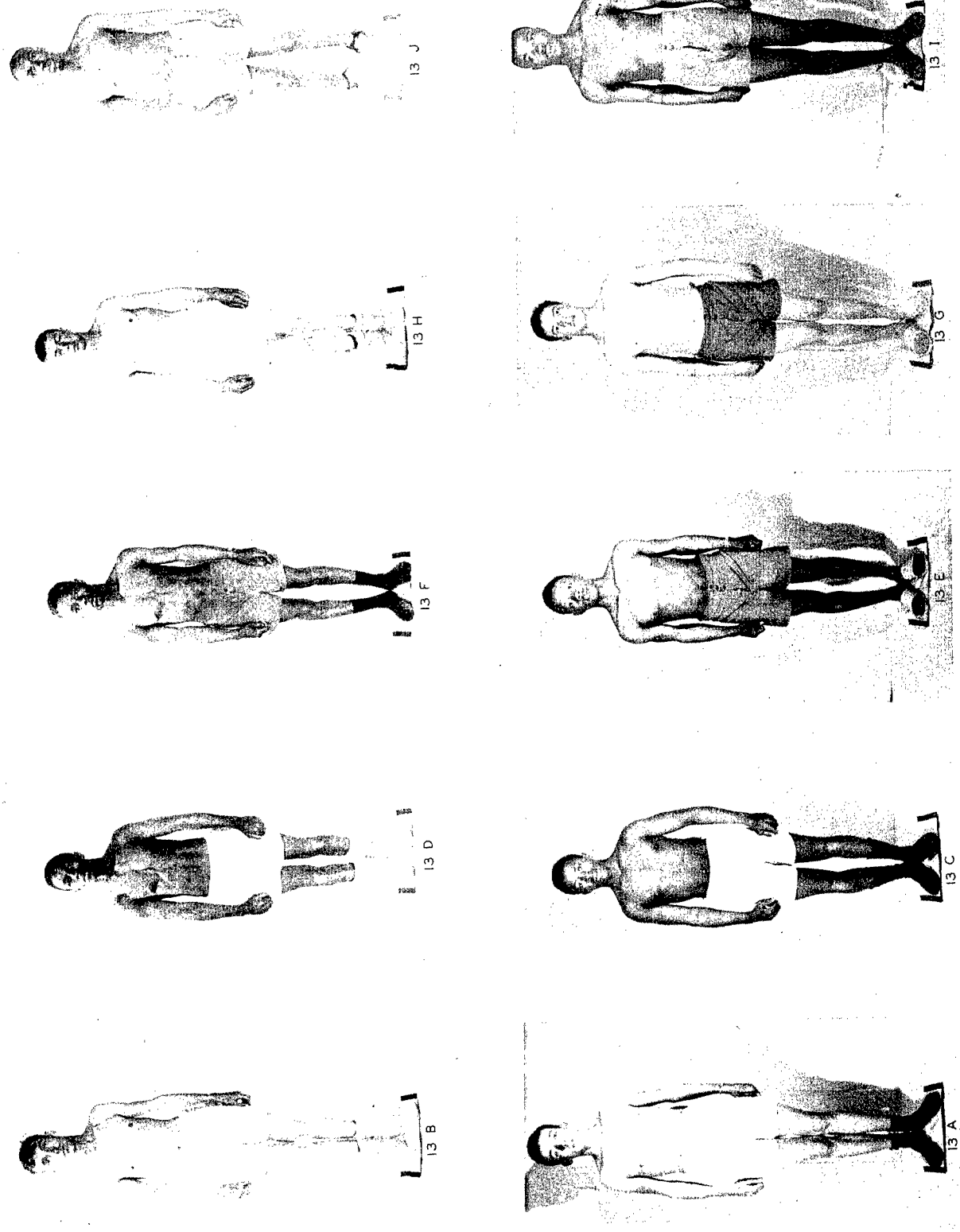

13 J
13 I
13 H
13 G
13 F
13 E
13 D
13 C
13 B
13 A

FIGURE III. 14. SUBJECTS OF FLIGHT 2 BEFORE AND AFTER EXPERIMENTAL PERIODS (2000 AND 3000 CALORIES, LIMITED WATER, HARD WORK).

A. SUBJECT 29: PRE

B. SUBJECT 29: 0/100/0 2000 L

C. SUBJECT 34: PRE

D. SUBJECT 34: 30/0/70 2000 L

E. SUBJECT 37: PRE

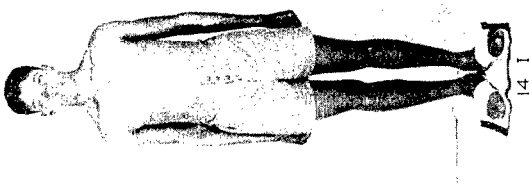
F. SUBJECT 37: 2/20/78 2000 L

G. SUBJECT 41: PRE

H. SUBJECT 41: 15/52/33 2000 L

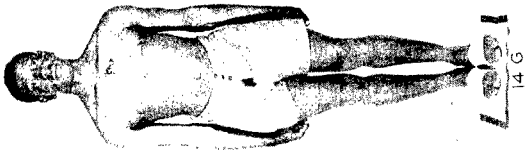
I. SUBJECT 43: PRE

J. SUBJECT 43: 15/52/33 3000 L

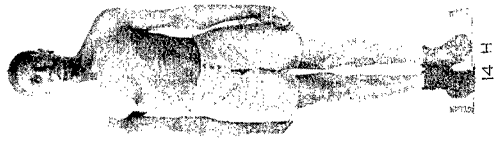


14 I

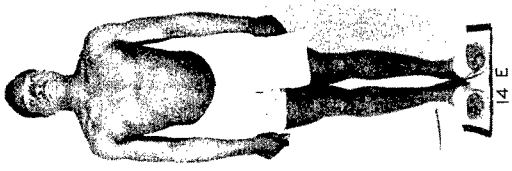
14 J



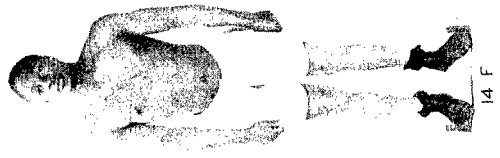
14 G



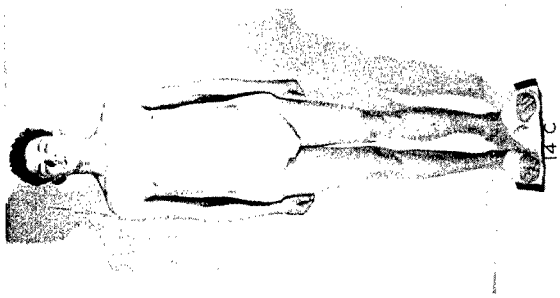
14 H



14 E

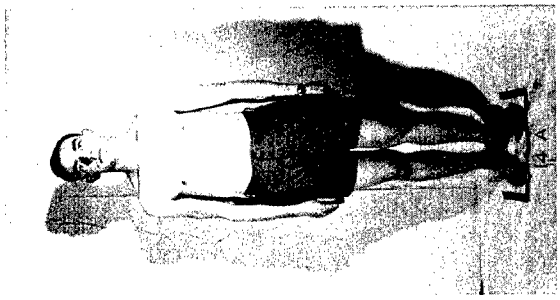


14 F



14 C

14 D



14 A

14 B

FIGURE III. 15. SUBJECTS OF FLIGHT 3 BEFORE AND AFTER EXPERIMENTAL PERIODS (STARVATION AND 1000 CALORIES, UNLIMITED WATER, LIGHT WORK).

A. SUBJECT 46: PRE

B. SUBJECT 46: ST 0 U

C. SUBJECT 49: PRE

D. SUBJECT 49: 0/100/0 1000 U

E. SUBJECT 54: PRE

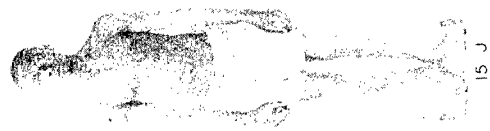
F. SUBJECT 54: 30/0/70 1000 U

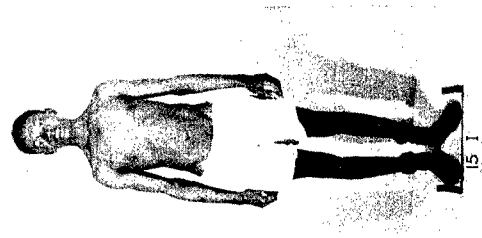
G. SUBJECT 57: PRE

H. SUBJECT 57: 2/20/78 1000 U

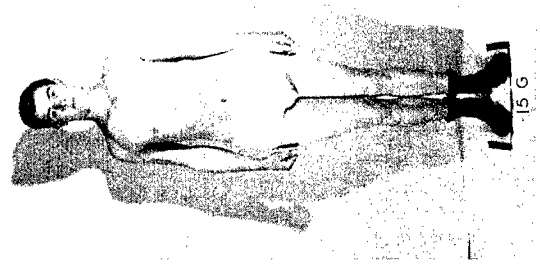
I. SUBJECT 62: PRE

J. SUBJECT 62: 15/52/33 1000 U


15 J


15 I


15 H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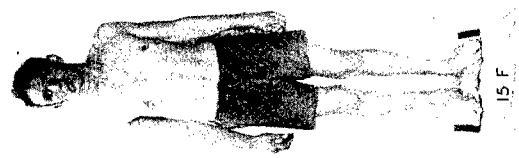
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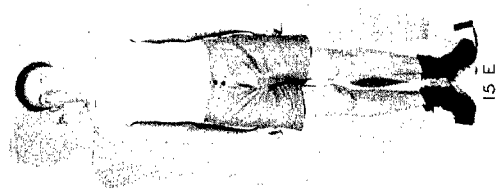
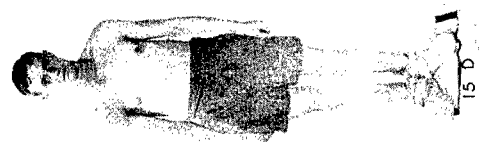

15 E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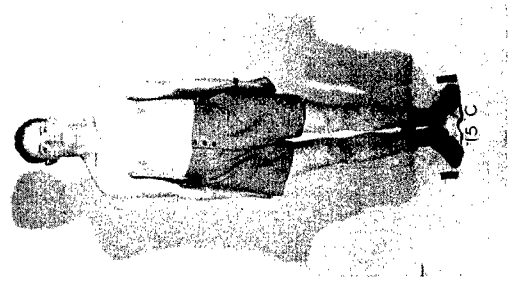
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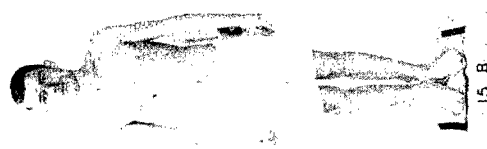
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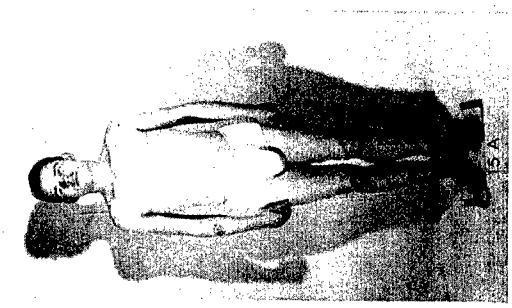

15 A

FIGURE III. 16. SUBJECTS OF FLIGHT 3 BEFORE AND AFTER EXPERIMENTAL PERIODS (2000 AND 3000 CALORIES, UNLIMITED WATER, LIGHT WORK).

A. SUBJECT 51: PRE

B. SUBJECT 51: 0/100/0 2000 U

C. SUBJECT 56: PRE

D. SUBJECT 56: 30/0/70 2000 U

E. SUBJECT 61: PRE

F. SUBJECT 61: 2/20/78 2000 U

G. SUBJECT 64: PRE

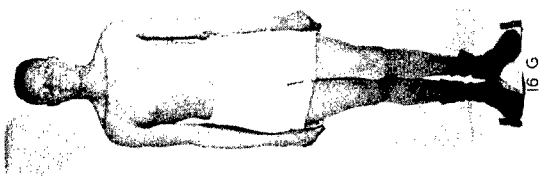
H. SUBJECT 64: 15/52/33 2000 U

I. SUBJECT 66: PRE

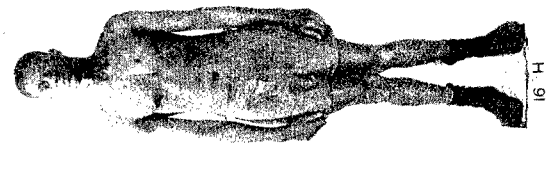
J. SUBJECT 66: 15/52/33 3000 U

16 I

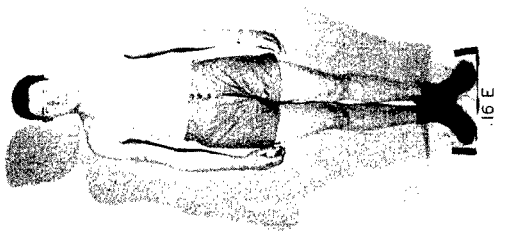
16 J



16 G

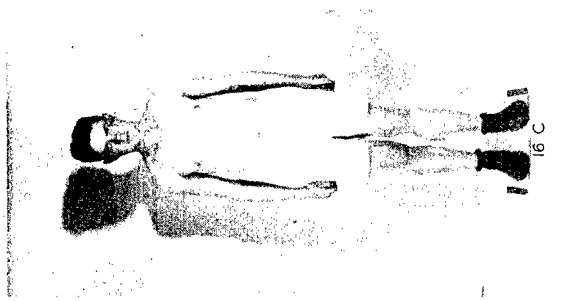


16 H



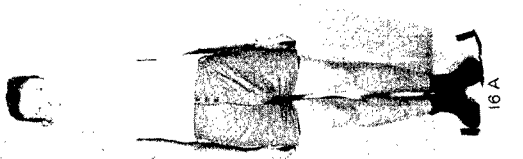
16 E

16 F



16 C

16 D



16 A

16 B

C. RENAL FUNCTION AND OSMOTIC REGULATION

1. Urinary Volume

Twenty-Four Hour Volume. The pre-period means for the 24-hour urinary output by the five groups of subjects did not differ significantly (Table III. 15). The standard deviation was of the order of 500 to 750 ml/day.

Experimental regimens: Mean data for the 24-hour excretion of urine in the relation to the several experimental regimens are summarized in Table III. 16. Since daily volumes for the controls were not collected, it is doubtful that the variations are anything more than random ones. The alterations in urinary volume for the other subjects accurately reflect the variations shown by the minute urine volume (v.s.). Work load had no appreciable effect on the 24-hour output of urine. Limitation of water reduced the urine volume and the reduction tended to be inversely related to the intake of osmotically active substances. There was a marked reduction among subjects on 0/100/0 and 2/20/78 and a lesser reduction among those on 15/52/33 and 30/0/70.

Recovery diuresis: The notable observation of the recovery periods concerns the rather consistently large increase in 24-hour output in REC II (Table III. 17). It was the impression of all those handling urinary samples that a great increase in urine output occurred when the subjects changed from the 5-in-1 ration to the garrison ration. Several subjects complained to the supervisory investigator: "Doc, what's the matter? All I do is pass water." Study of the daily urine volumes around the period demonstrates conclusively that a true diuresis occurred on 29 March (and in some cases also 30 March), the time of transfer from 5-in-1 ration to garrison ration. This phenomenon has been called the "recovery diuresis" (Table III. 17A, B, C). The diuresis was of the order of 500 ml. It occurred at a time when the fluid intake was relatively low. It was statistically significant in spite of the large standard deviations.

What caused this diuresis? Two factors are possibly responsible. (1) It has been observed before that changing from packaged rations to customary foods frequently causes a diuresis (R. E. Johnson, personal communication), perhaps related to some nutrient difference between packaged and fresh rations. (2) Exposure to cold can elicit a diuresis. Reference to Figure III. 1 shows that on the day these men began eating the garrison ration there was a cold wave. Maximum temperature fell from 66° to 40°F and minimum temperature from 40° to 28°F. March 29 was a cold rainy day. At the present stage of analysis of our data it is not possible to develop either argument further.

Cold diuresis: The possibility remains that the phenomenon of cold diuresis may have been present on other occasions. During the period at Camp McCoy a sharp cold wave occurred and temperatures fell steeply to subzero levels on March 15 (Figure III. 1). Study of the data at this time is complex, for the subjects were being subjected to a variety of experimental regimens. Analysis was limited to men who were on unrestricted water consumption. A suggestive increase in the urine output for men doing hard work appeared on March 13 and 14. It was most striking among the men on 15/52/33 2000 and 3000

and 30/0/70 1000 and 2000. The increased urinary volume came at a time when fluid intake was increasing and so it is difficult to label the elevated urine output as a diuresis due to cold. That the urine volumes then fell sharply on March 15 and 16 --- in spite of continued relatively high or rising fluid intake --- suggests that a diuresis may have occurred. Men doing light work did not show such suggestive alterations in their 24-hour urinary outputs.

Minute Urinary Volume. Since the minute urinary volume was the basis for many calculations in function tests, it was imperative that unreliable values be detected and discarded. Review of the data indicated that on several occasions the minute volume was excessively high --- values exceeded 5 ml/min. A number of these high values were obtained when the urinary collection period had been less than 80 minutes. Since the urine had been collected by voluntary voiding, it was probable that when the collection period was less than 80 minutes, the experimental error became quite large. All minute urine volumes were, therefore, discarded in which the period of collection was not at least 80 minutes.

Statistical study of the remaining data for the two pre-periods and the second week of recovery indicated that there remained some high minute urine volumes. These high values suggested that the subject was actively diuresing during the two-hour test. Since diuresis may yield unphysiological results as regards rate of excretion of minerals and nitrogenous compounds (e.g., creatinine) by the resting subject, these high values had to be eliminated. The criterion adopted was: any minute urine volume in the pre-periods or the second week of recovery exceeding mean + 2.5 times the standard deviation was designated as a diuretic value and discarded. A total of seven tests in 170 were eliminated in the pre-periods and three in 98 in REC II. Discarding these ten values did not materially effect the mean minute urine volume (Table III. 18).

Control data: The two weeks of pre-period were the intervals of time when control data was collected. Since, on the basis of the 1953 study, most functions had returned to normal after one week of recovery, the second week of the recovery period should also furnish normative values. The frequency distributions of the minute urine volumes are summarized in Table III. 19 and Figure III. 17. The data shown deal with the two pre-periods and REC II. All unreliable values (as defined above) have been discarded.

In the pre-periods the mode was 0.58 ml/min (Figure III. 17). There was a secondary mode at 2.08 ml/min. In REC II the mode was 1.58 ml/min and there was a secondary mode at 0.58 ml/min. The increased volume of the recovery period is reflected in the increased value for the mean (Table III. 18). Apparently there was a tendency for the subjects to excrete somewhat larger volumes of urine in REC II than in the pre-periods, but in this analysis the differences were significant. Both means and modes represent physiological values.

The pre-period data for the five groups of subjects are summarized in Table III. 20. The significant observation there concerns the differences between the four flights. At first we thought that Flights 2 and 4 might be

significantly different, but such did not prove to be the case. The mean daily fluid intakes for the four flights, however, did not vary appreciably; they were 1976, 2009, 1917, and 1912 ml, respectively. It was then hypothesized that the differences between flights might reflect a diurnal cycle, because in the pre-period Flights 1 and 3 were tested between 1300 and 1500 and 2 and 4 between 1500 and 1700. Whether such a diurnal cycle exists is not known, but such a cycle might explain other differences between the flights, which have appeared as the analysis of the various data has progressed.

Experimental regimens: There were no striking differences between men performing hard work and those doing light work. There was, on the other hand, a consistent and marked reduction in the minute volume among those men subsisting on the limited water regimens. The absolute level of the minute urine volume in these men tended to increase as the solute load increased (e.g., compare 0/100/0 2000 and 30/0/70 2000). These data and those for the 24-hour urinary output were closely similar to those observed in the 1953 winter study (WADC TR 53-484).

Recovery: In the recovery periods the minute urinary volumes were increased and there were more high values than in the pre-periods. These high volumes were presumably related to a high positive water balance together with a large water intake in the two recovery weeks.

TABLE III. 15

PRE-PERIOD DATA ON TWENTY-FOUR HOUR URINARY VOLUME
(ml/day)

Groups of Subjects	PI		PII	
	M	Range	M	Range
Flight 1	1592	600-3280	1661	625-4040
Flight 2	1567	695-3400	1509	580-2980
Flight 3	1508	720-2860	1570	810-3150
Flight 4	1447	860-3170	1434	700-2840
Control	----	--------	1530	702-3820

TABLE III. 16

TWENTY-FOUR HOUR URINARY OUTPUT
(ml/day)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	1690	1407	886	1128	2061	1567	1567	1618	1490	1933
	L	1673	763	528	1340	2096	1554	743	597	1662	2066
0/100/0	U	2020	1830	1349	1964	2273	1535	862	697	1260	2266
1000	L	1786	684	463	1467	2406	1380	708	504	1410	1915
0/100/0	U	1423	872	798	1500	1834	1406	1536	1060	1492	2065
2000	L	1083	480	471	1035	1386	1834	669	471	1831	1876
2/20/78	U	1748	1569	1397	2012	2577	1504	1622	1606	1730	1962
1000	L	1048	589	532	1104	1718	1299	752	433	1315	1886
2/20/78	U	2181	2620	1840	2135	2321	1857	1968	2780	1961	2672
2000	L	1760	902	641	2204	2298	1354	660	550	1759	2068
15/52/33	U	1440	1554	1635	1720	2232	1707	1514	988	2406	2237
1000	L	2018	798	664	1948	2482	1370	779	500	1286	2052
15/52/33	U	1482	1284	1375	1660	2090	1496	1346	1030	1445	1646
2000	L	1750	1032	803	2010	2810	1484	737	647	1792	1952
15/52/33	U	1912	1349	1325	1764	1837	1521	1461	1289	1864	2062
3000	L	1254	888	873	1615	1706	1376	866	624	2346	1972
30/0/70	U	1094	1594	1419	1539	1977	1373	1381	1502	1281	2063
1000	L	1356	1141	852	1481	2246	1242	775	699	1585	1722
30/0/70	U	1224	1726	1448	1106	1846	1415	2581	1949	1480	1972
2000	L	1522	982	1116	1959	2053	1465	1236	1067	1875	1920
Control	U	2128	----	1806	----	2425	1271	----	1461	----	1615
	L	1516	----	2126	----	1593	1192	----	1487	----	1371

*Mean values for PI and PII.

TABLE III. 17

RECOVERY DIURESIS

A. MEAN DAILY OUTPUT OF URINE

Flight	M26	M27	M28	M29	M30	M31	A1	A2
	Mean Daily Urine Volume, ml							
1	2016	2043	1894	2537	2243	1917	1844	2135
2	1907	1893	1809	2465	2436	2035	1840	1974
3	1885	1888	1679	2515	2149	2018	1905	2077
4	1938	2083	1678	2375	2284	1820	1703	1910

B. MEAN DAILY FLUID INTAKE*

Flight	M26	M27	M28	M29	M30	M31	A1	A2
	Mean Daily Fluid Intake, ml							
1	2405	2578	2230	1610	1636	1743	1754	2079
2	2459	2779	2121	1781	1814	2513	1895	2190
3	2711	1903	2088	1702	1806	2006	1847	1898
4	2855	1899	2797	1500	1919	1988	1689	1956

*Preformed water in food not included.

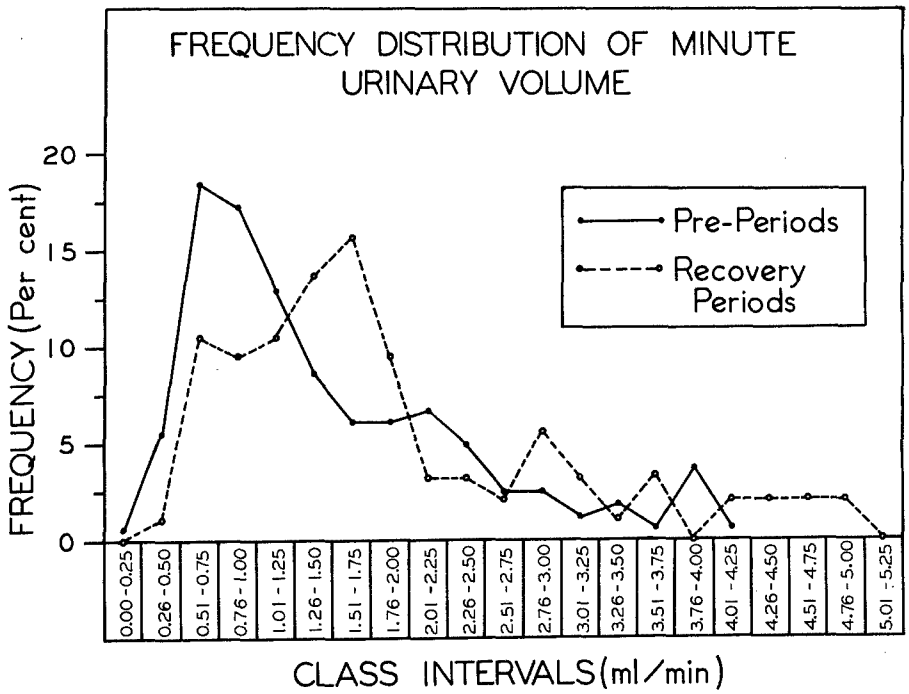


FIGURE III. 17. FREQUENCY DISTRIBUTION OF MINUTE URINARY VOLUME.

TABLE III. 17 (Contd)

C. STATISTICAL ANALYSIS: RECOVERY DIURESIS

	Mean ± s.d.			
Flight	M29	M26 - M28 M31 - A2	"t"	P
1	2537 ± 805	1975 ± 545	3.16	0.01
2	2465 ± 715	1910 ± 665	3.40	0.01
3	2515 ± 415	1910 ± 495	4.49	0.01
4	2375 ± 530	1860 ± 475	4.16	0.01

TABLE III. 18

CALCULATION OF DIURETIC LEVEL OF MINUTE URINE VOLUME (ml/min)

Period	No. of Tests	Mean ± s.d.	Diuretic Level	Corrected Mean*
Pre I & II	170	1.48 ± 1.15	4.36	1.34
Rec II	98	1.89 ± 1.35	5.27	1.73

*After elimination of values as discussed in text.

TABLE III. 19

FREQUENCY DISTRIBUTION OF MINUTE URINE VOLUMES:
PRE- AND RECOVERY PERIODS

Class Intervals	Number		Per cent*	
	Pre I & II	Rec II	Pre I & II	Rec II
0.00-0.25	1	0	0.6	0.0
0.26-0.50	9	1	5.5	1.1
0.51-0.75	30	10	18.4	10.5
0.76-1.00	28	9	17.2	9.5
1.01-1.25	21	10	12.9	10.5
1.26-1.50	14	13	8.6	13.7
1.51-1.75	10	15	6.1	15.7
1.76-2.00	10	9	6.1	9.5
2.01-2.25	11	3	6.7	3.2
2.26-2.50	8	3	4.9	3.2
2.51-2.75	4	2	2.5	2.1
2.76-3.00	4	5	2.5	5.3
3.01-3.25	2	3	1.2	3.2
3.26-3.50	3	1	1.8	1.1
3.51-3.75	1	3	0.6	3.3
3.76-4.00	6	0	3.7	0.0
4.01-4.25	1	2	0.6	2.1
4.26-4.50	-	2	---	2.1
4.51-4.75	-	2	---	2.1
4.76-5.00	-	2	---	2.1
5.01-5.25	-	0	---	0.0
Total	163	95	99.9	100.3

* X^2 = 40.16; P is less than 0.01.

TABLE III. 20

PRE PERIOD DATA ON MINUTE URINARY VOLUME
(ml/min)

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
Flight 1	2.41	1.20	49.8	1.35	0.71	52.6
Flight 2	1.20	0.82	68.3	1.38	0.74	53.6
Flight 3	1.79	0.82	45.9	1.80	0.79	43.8
Flight 4	1.09	0.76	69.5	1.20	0.67	55.8
Controls	0.89	0.40	44.9	1.18	0.67	56.7

Statistical Analysis of Data. P I: Flight 1 vs. Flight 2, t = 3.24, P = 0.01; Flight 3 vs. Flight 4, t = 2.28, P = 0.05. P II: Flight 1 vs. Flight 2, Not significant; Flight 3 vs. Flight 4, t = 2.45, P = 0.02.

TABLE III. 21

MINUTE URINARY VOLUME
(ml/min)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	2.31	0.62	1.34	1.25	3.77	1.83	1.09	2.55	2.18	1.76
	L	1.78	0.44	0.42	1.43	1.70	1.24	0.53	0.57	1.74	1.26
0/100/0	U	1.87	0.33	0.32	2.13	3.17	1.84	0.48	0.75	2.77	1.23
1000	L	2.81	0.39	0.34	1.67	1.82	0.78	0.34	0.26	1.85	1.90
0/100/0	U	0.88	0.42	0.60	2.19	1.62	1.34	0.70	0.62	2.37	1.02
2000	L	0.91	0.18	0.32	1.30	0.93	1.18	0.24	0.36	1.74	1.08
2/20/78	U	2.23	1.37	0.77	2.53	2.43	1.84	0.62	1.47	1.83	1.15
1000	L	0.78	0.30	0.36	0.80	1.31	1.08	0.50	0.59	2.05	1.16
2/20/78	U	1.93	1.86	2.47	2.17	2.52	2.13	1.19	2.10	4.32	3.39
2000	L	1.11	0.77	0.83	1.46	1.68	1.32	0.48	0.56	3.64	1.70
15/52/33	U	1.11	0.33	0.48	2.43	3.01	2.27	1.16	1.53	1.26	2.68
1000	L	1.19	0.48	0.46	1.86	0.98	1.32	0.30	0.82	2.62	2.05
15/52/33	U	1.49	2.38	2.60	3.76	3.23	2.57	0.79	1.89	0.55	1.88
2000	L	1.37	0.83	0.70	1.58	2.29	1.08	0.61	0.50	1.78	1.60
15/52/33	U	2.10	4.00	2.07	4.90	2.49	1.29	0.76	0.97	1.58	3.16
3000	L	0.64	0.92	0.69	0.88	0.82	2.28	0.76	0.65	3.38	2.36
30/0/70	U	1.74	2.68	2.19	2.20	3.32	1.11	1.21	1.00	2.17	1.34
1000	L	1.12	0.75	0.72	1.60	1.55	0.48	0.57	0.54	1.78	1.31
30/0/70	U	1.15	1.48	0.88	1.15	1.96	2.20	2.84	1.87	1.35	0.86
2000	L	0.97	0.78	0.92	2.37	2.44	1.56	1.08	0.96	3.42	1.68
Control	U	1.20	0.82	0.88	1.01	1.70	1.45	0.83	2.62	0.99	1.05
	L	1.64	1.57	2.08	0.81	0.63	0.76	0.75	3.60	0.56	0.87

*Mean value for PI and PII.

2. Qualitative Examination

The qualitative tests performed routinely were for sugar, albumin, ketone bodies, and formed elements (Addis count). Acetonuria will be discussed in the section on Acid-Base Balance as it is more a metabolic than renal phenomenon.

Glycosuria. In the 594 two-hour tests only one specimen reacted positively for sugar (Subject 19, Week 5, plus 1 test). We conclude that metabolic or renal glycosuria was never present in these subjects.

Albuminuria. Albuminuria was observed in a number of the two-hour urinary specimens (Tables III. 22 and 23). In the case of both the flight leaders and the volunteer subjects, albuminuria was rare in the pre-period. During the experimental period, the incidence increased. Numerous positive reactions were observed in the second week, 14 subjects showing +2. In the recovery period the incidence and intensity of the reaction decreased. The phenomenon was strikingly absent among fasting men doing hard work, and men subsisting on meat bar at 1000 Cal/day. Water intake, experimental mixture, and work load, otherwise, seemed to have little to do with the occurrence of albuminuria. The common factors were exposure to cold weather and the general field situation. It is well-known that cold can induce the appearance of albuminuria. The albuminuria observed in this test was in striking contrast to the experience with eight volunteer students living under more comfortable conditions during the winter of 1953. At that time albuminuria was observed on only one occasion and then in a fasting subject.

In recovery albuminuria decreased in intensity in both the flight leaders and the experimental subjects, especially in the light work groups. We interpret this as being due to withdrawal from the stresses of the field phase.

Casts and Red Cells. The two-hourly urinary excretion of casts and red cells by the flight leaders and the volunteer airmen in the pre-period are summarized in Table III. 24. Of the 68 specimens collected from flight leaders only two, or 2.9%, showed red blood cells or casts. No subject excreted these formed elements twice. Their appearance bore no relation to the three phases of the investigation. During the pre-period 170 specimens, or 8.2%, showed red blood cells and one or 0.6% showed casts. The number of red cells in these 14 specimens ranged from 3.5 to 37.2 thousands/2 hr. It is significant to note that no formed elements were recorded for control urinary specimens collected from the volunteer students during the winter of 1953.

There was a marked increase in the number of red blood cells during the experimental periods, the increase being generally greatest during the second week (Table III. 25). Several trends are evident in these observations: (1) A greater number of cells was excreted by men doing hard work than by those doing light work, notable exceptions being 2/20/78 2000 L and 15/52/33 3000 U. (2) Regardless of work load, starvation and the 0/100/0-regimen were more consistently correlated with the occurrence of red cells than any other diets. (3) Limited water tended to be correlated with the appearance of red cells more often than unlimited water. A final interpretation of these data will depend upon a correlation with the clinical observations.

During the recovery periods there was a considerable reduction in the occurrence of red blood cells. In fact they had disappeared in all subjects except those who had previously been on ST 0, 0/100/0, or 2/20/78.

Casts were observed less often than red cells (Table III. 26). During pre-periods and recovery periods they were rare. Their maximum incidence was during the second week of the experimental period. More casts were noted in the urine from men doing hard work than in the urine from men doing light work. Limited water was much more conducive to the appearance of casts than unlimited water. As in the case of red cells, the regimens most frequently associated with casts were starvation and pure carbohydrate.

White Blood Cells. The urinary sediment of most of the subjects contained white blood cells. During the pre-periods the two-hourly output of these formed elements was entirely normal for this age group as judged by data collected in 1953 and the usual clinical standards (Table III. 27). The ration controls, representing an older age group, excreted more white cells than the volunteer airmen.

The experimental periods were characterized by a wide individual variability. In spite of this variance, at least one trend is evident. There was a general increase in the mean two-hourly output of leukocytes, which was most striking in EXP II. In general, the trend was independent of caloric and water intakes, work load, and nutrient mixture. It seemed to be a non-specific (non-discriminatory) reaction to the stresses of the field phase. Although the ration controls as a group failed to exhibit the reaction, the fact that the positive controls did supports the hypothesis of non-specificity.

In the recovery periods, especially REC I, there was a persistence of this reaction; in some cases maximal values were reached at this time. There was a definite trend toward lower rates of excretion of leukocytes in REC II, the noteworthy exceptions being 15/52/33 1000 (both work loads) and 0/100/0 2000 (light work) (Table III. 28).

Epithelial Cells. The rate of excretion of epithelial cells during the pre-periods (Table III. 29) was in satisfactory agreement with the data of 1953. In the experimental periods (Table III. 30) there was a non-specific reaction reminiscent of that seen in the output of white blood cells. The course of recovery was similar for these two formed elements.

Comment on Addis Count and Albuminuria. These qualitative measurements permit an important conclusion. In so far as renal function is concerned, the marked accentuation of albuminuria and the increased output of casts, red blood cells, leukocytes, and epithelial cells --- especially in EXP II ---, suggests that renal dysfunction probably occurred in most subjects. Because the functional disturbance was so general among the subjects, it was more probably an effect of the stresses of the field phase than an effect of water, work load, or nutrient combination.

TABLE III. 22

ALBUMINURIA AMONG RATION CONTROLS

Subject Code No.	Albuminuria (0 to +4)					
	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6
90	0	0	0	0	tr	tr
91	0	0	tr	0	0	tr
92	0	0	tr	+1	0	tr
93	0	0	0	tr	0	0
94	0	0	0	+1	0	0
95	0	0	0	tr	0	tr
96	0	0	0	tr	0	0
97	-	0	0	tr	tr	0
98	0	0	+1	0	tr	0
99	0	0	0	tr	0	0
100	0	0	0	+1	0	-
101	0	0	+1	tr	0	0

TABLE III. 23

ALBUMINURIA AMONG EXPERIMENTAL SUBJECTS

Experimental Regimen		Albuminuria (0 to +4)									
		Hard Work					Light Work				
		Pre	Exp I	Exp II	Rec I	Rec II	Pre	Exp I	Exp II	Rec I	Rec II
ST 0	U	0,0,0,0	0,0,0,0	0,0,0,0	0,0,0,0	0,0,0,0	0,0,0	0,0,0	+1,+2	0,tr,tr	0,tr,tr
	L	0,0,0,0	0,0,0,0	0,0,0,0	0,0,0,0	0,0,0,0	0,0,0	0,0,0	+1,+2	0,0,tr	0,0,0
0/100/0	U	0,0	0	0	0,0	0,0	0,0	0,0	+2,+2	tr,tr	0,0
1000	L	0,0	0,tr	tr,+2	0,tr	0,tr	0,0	0,0	+2,+2	0,0	0,0
0/100/0	U	0,0	0,tr	0,0	0,0	tr,tr	0,0	0,tr	+1,+2	0,0	0,0
2000	L	0,0	0,0	+1,+1	tr,+1	tr,tr	0,0	0,0	+2,+2	0,0	0,0
2/20/78	U	0,0	0,0	+1,+1	+1,+1	tr,tr	0,0	0,0	tr,tr	0,0	0,0
1000	L	0,0	0,0	tr,tr	0,0	tr,tr	0,0	0,0	tr,+1	0,0	0,0
2/20/78	U	0,0	0,0	0,+1	0,tr	tr,tr	0,0,0	0,0,0	+1,+2	0,0,tr	0,0,0
2000	L	0,0	0,0	0,tr	0,0	tr,tr	0,0	0,0	tr,tr	0,tr	0,0
15/52/33	U	0,0	0,0	+1,+1	0,0	tr,tr	0,0	0,0	+1,+2	0,tr	0,0
1000	L	0,0	0,+1	0,+2	tr,tr	tr,+1	0,0	0,0	+1,+1	0,0	0,0
15/52/33	U	0,0	0,0	0,tr	0,0	tr,tr	0,0	0,0	tr,+1	0,tr	0,tr
2000	L	0,0	0,0	tr,tr	0,tr	tr,tr	0,0	0,0	tr,+1	0,0	0,0
15/52/33	U	0,0	0,0	0,0	0,tr	0,tr	0,0	0,0	0,tr	0,0	0,0
3000	L	0,0	tr,tr	tr,tr	0,tr	tr,tr	0,0	0,0	tr,+1	0,0	0,0
30/0/70	U	0,0	0,0	0,+1	0,0	0,tr	0,0	0,0	0,0	0,0	0,tr
1000	L	0,0	0,0	0,0	tr,+1	tr,+1	0,tr	0,0	0,0	0,0	0,0
30/0/70	U	0,0	0,0	tr,tr	0,0	0,0	0,0	0,0	0,tr	0,0	0,0
2000	L	0,0	0,0	tr,tr	tr,+1	tr,tr	0,0	0,0	+1,+2	0,0	0,0

TABLE III. 24

PRE PERIOD DATA ON ADDIS COUNT: RED BLOOD CELLS AND CASTS

Ration	Total No. of Subjects	Total No. of Specimens	%Positive Specimens	
			Red Blood Cells	Casts
A	12	68	2.9[1]	2.9[3]
5-in-1	87	170	8.2[2]	0.6[4]

[1] 6.5, 7.5 thousands/2 hr

[2] 3.5, 7.1, 10.3, 12.4, 12.4, 12.4, 15.4, 20.6, 22.4, 26.9, 27.2, 29.0, 37.2 thousands/2 hr

[3] 7.3, 108.7 thousands/2 hr

[4] 9.2 thousands/2 hr

TABLE III. 25

MEAN ADDIS COUNT IN EXPERIMENTAL SUBJECTS: RED BLOOD CELLS

Experimental Regimen		Red Blood Cells, Thousands/2 hr									
		Hard Work					Light Work				
		Pre	Exp		Rec		Pre	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	0	7.2	10.4	12.4	0	0	0	0	0	8.4
	L	4.9	8.8	30.1	0	0	0	8.5	4.9	0	0
0/100/0	U	9.3	4.9	13.0	0	0	0	3.3	8.7	0	0
1000	L	0	5.3	35.5	0	5.2	4.1	4.4	10.7	0	0
0/100/0	U	0	0	5.3	0	0	0	0	0	0	0
2000	L	0	33.2	15.8	0	0	0	1.5	0	0	7.2
2/20/78	U	0	0	0	9.8	0	0	0	0	0	0
1000	L	7.7	0	10.0	0	0	0	0	0	0	0
2/20/78	U	0	0	16.4	0	0	0	9.5	0	0	0
2000	L	6.2	0	0	0	0	0	6.4	20.6	0	0
15/52/33	U	0	0	0	0	0	0	0	0	0	0
1000	L	0	0	0	0	0	6.7	0	0	0	0
15/52/33	U	0	0	0	0	0	5.2	0	0	0	0
2000	L	0	6.8	0	0	0	0	0	3.4	0	0
15/52/33	U	3.8	0	9.4	0	0	0	9.4	25.6	0	0
3000	L	0	0	0	0	0	0	0	9.4	0	0
30/0/70	U	2.2	9.4	0	0	0	0	0	0	0	0
1000	L	0	0	4.0	0	0	1.8	0	0	0	0
30/0/70	U	5.6	0	0	0	0	0	0	0	0	0
2000	L	0	0	0	0	0	0	0	5.8	0	0

TABLE III. 26

MEAN ADDIS COUNT IN EXPERIMENTAL SUBJECTS: CASTS

Experimental Regimen		Casts, Thousands/2 hr									
		Hard Work					Light Work				
		Pre	Exp		Rec		Pre	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	0	12.5	2.5	0	0	0	0	0	0	0
	L	0	4.8	11.7	0	0	0	0	6.2	4.7	0
0/100/0	U	0	0	1.5	0	0	0	0	0	0	0
1000	L	0	0	13.6	0	0	0	2.2	3.6	0	0
0/100/0	U	0	0	0	0	0	0	0	0	0	0
2000	L	0	0	3.0	0	0	0	0	0	0	0
2/20/78	U	0	0	0	0	0	0	0	0	0	0
1000	L	0	0	0	5.6	0	0	0	3.6	0	0
2/20/78	U	0	2.9	0	0	0	0	0	0	0	0
2000	L	0	0	0	0	0	0	0	0	0	0
15/52/33	U	0	0	0	0	0	0	0	0	0	0
1000	L	0	0	0	0	0	0	0	4.6	0	0
15/52/33	U	0	0	0	0	0	0	0	0	0	0
2000	L	0	0	2.9	0	0	0	0	0	0	0
15/52/33	U	0	0	0	0	0	0	0	0	0	0
3000	L	0	0	4.2	0	0	0	0	0	0	0
30/0/70	U	0	0	0	0	0	0	0	0	0	0
1000	L	0	0	0	0	0	0	0	0	0	9.8
30/0/70	U	0	0	0	0	0	0	0	0	0	0
2000	L	2.6	0	0	0	0	0	0	0	0	0

TABLE III. 27

PRE PERIOD DATA ON ADDIS COUNT:
WHITE BLOOD CELLS
(Thousands/2 hr)

Groups of Subjects	PI		PII	
	Mean	Range	Mean	Range
Flight 1	6.0	0.0 - 64.5	8.0	0.0 - 55.4
Flight 2	7.3	0.0 - 100.8	14.5	0.0 - 82.8
Flight 3	3.1	0.0 - 34.4	7.3	0.0 - 81.8
Flight 4	2.6	0.0 - 22.4	7.3	0.0 - 62.9
Controls	19.1	0.0 - 49.7	13.7	0.0 - 70.6

TABLE III. 28

ADDIS COUNT: WHITE BLOOD CELLS
(Thousands/2 hr)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	0.0	16.1	5.2	26.3	0.0	5.2	39.7	130.2	0.0	25.2
	L	2.6	10.9	23.4	104.7	28.1	7.8	33.7	48.5	39.2	29.3
0/100/0	U	25.4	6.9	22.4	70.0	0.0	3.8	8.1	168.6	0.0	48.6
1000	L	11.4	5.3	148.2	16.9	20.8	4.1	15.7	110.4	0.0	7.0
0/100/0	U	0	40.0	50.5	71.5	12.8	22.1	6.8	108.6	33.3	44.4
2000	L	8.0	25.3	12.8	6.3	0.0	14.2	4.8	1,118.6	259.9	8,200.0
2/20/78	U	25.1	10.5	107.3	92.5	64.4	0.0	25.0	29.2	0.0	14.8
1000	L	32.8	53.6	224.0	952.6	72.9	12.8	11.4	132.0	444.6	319.8
2/20/78	U	2.8	18.0	33.0	19.4	0.0	16.4	20.0	90.2	0.0	8.8
2000	L	3.1	0.0	81.2	35.7	34.0	0.0	12.8	26.5	48.5	0.0
15/52/33	U	8.2	6.7	57.2	23.0	93.6	0.0	23.3	53.2	0.0	35.8
1000	L	0.0	54.4	390.6	2,486.1	246.0	0.0	17.3	31.3	91.2	131.0
15/52/33	U	0.0	0.0	36.0	0.0	63.0	0.0	4.8	0.0	0.0	8.5
2000	L	13.2	30.0	32.2	82.4	0.0	0.7	3.5	23.8	10.7	0.0
15/52/33	U	3.9	0.0	37.1	46.4	0.0	0.0	9.4	1,249.6	0.0	31.5
3000	L	4.5	25.6	31.4	40.6	4.8	3.7	10.9	453.4	18.3	21.8
30/0/70	U	4.3	0.0	0.0	28.7	41.0	15.3	7.6	27.4	29.0	27.6
1000	L	4.4	4.2	36.4	399.4	0.0	1.9	6.4	25.6	0.0	123.8
30/0/70	U	3.9	12.3	3.4	20.3	9.0	0.0	0.0	32.8	7.6	32.8
2000	L	36.1	5.0	269.4	387.3	11.8	0.0	0.0	24.3	0.0	0.0
Control	U	6.8	3.6	46.0	7.4	6.0	2.6	2.2	7.3	37.1	26.7
	L	37.5	0.0	8.1	36.8	5.7	11.8	0.0	0.0	256.9	10.7

*Mean values for PI and PII.

TABLE III. 29

PRE-PERIOD DATA ON ADDIS COUNT: EPITHELIAL CELLS
(Thousands/2 hr)

Groups of Subjects	PI		PII	
	Mean	Range	Mean	Range
Flight 1	5.2	0.0 - 32.0	7.6	0.0 - 63.0
Flight 2	9.1	0.0 - 92.4	21.2	0.0 - 113.2
Flight 3	4.5	0.0 - 63.5	9.9	0.0 - 81.8
Flight 4	6.3	0.0 - 30.4	5.7	0.0 - 26.9
Controls	11.4	0.0 - 49.7	2.9	0.0 - 24.2

TABLE III. 30

ADDIS COUNT: EPITHELIAL CELLS
(Thousands/2 hr)

Experimental Regimen		Hard Work					Light Work				
		Pre*	Exp		Rec		Pre*	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	0.0	19.2	12.6	26.3	6.6	0.0	39.7	79.4	44.4	35.0
	L	32.1	20.2	29.4	11.6	33.0	1.0	18.2	48.5	7.1	0.0
0/100/0	U	9.3	4.4	14.0	70.0	23.4	3.8	8.1	45.3	0.0	42.4
1000	L	24.9	5.3	116.3	16.9	10.4	7.7	15.7	32.4	17.6	0.0
0/100/0	U	2.5	20.4	13.2	13.2	12.8	29.2	0.0	102.4	50.0	37.6
2000	L	11.8	25.3	15.5	60.9	13.7	11.6	4.8	52.0	38.1	24.0
2/20/78	U	23.7	26.4	193.7	97.7	158.0	1.3	25.0	50.0	20.2	25.0
1000	L	17.3	21.0	153.0	74.4	20.8	11.0	11.4	93.0	54.6	31.7
2/20/78	U	15.8	18.0	8.2	0.0	19.9	16.4	20.0	33.3	0.0	8.8
2000	L	13.3	0.0	81.4	62.6	0.0	4.8	9.6	26.5	48.5	0.0
15/52/33	U	0.0	8.8	24.1	41.2	0.0	0.0	23.3	61.8	22.0	8.2
1000	L	0.0	9.6	113.0	166.0	32.4	14.3	68.0	227.3	35.0	14.6
15/52/33	U	0.0	0.0	36.0	39.2	0.0	18.0	4.8	14.6	2.0	17.0
2000	L	10.4	22.1	30.0	79.2	0.0	1.9	3.5	37.4	10.7	13.0
15/52/33	U	0.0	0.0	37.1	84.3	0.0	0.0	9.4	229.6	0.0	0.0
3000	L	0.0	25.6	35.6	29.2	19.2	0.0	10.9	197.2	18.3	21.8
30/0/70	U	15.1	35.8	0.0	28.7	41.0	3.5	0.0	27.4	86.6	27.6
1000	L	0.0	4.2	17.0	121.5	20.5	5.1	6.4	25.6	0.0	41.2
30/0/70	U	3.9	12.3	3.4	30.7	18.0	0.0	0.0	82.2	49.2	8.8
2000	L	18.7	0.0	37.0	179.5	32.4	7.6	0.0	17.9	0.0	12.2
Control	U	3.1	3.6	46.0	3.7	6.0	2.6	2.2	7.3	15.1	7.0
	L	17.5	0.0	8.1	31.9	5.7	1.0	0.0	18.4	21.4	0.0

*Mean values for PI and PII.

3. Osmotic Regulation

Urine-Serum Osmolar Relationships. In the studies undertaken during winter, 1954, use of urinary specific gravity was discarded. Measurement of serum and urinary freezing-point depression is much more meaningful, and calculations based on such information yield considerably more theoretical and practical information.

The pre-period data for serum osmolarity, urinary minute osmotic excretion, and urine-serum (U/S) osmotic ratio are summarized in Table III. 31. The serum osmolar concentrations agree closely with those observed in the 1953 study. There are no significant differences between the means for the two pre-periods. The urinary minute osmolar output varied rather widely from group to group in the first week, but in the second, the inter-group variance was much smaller. In the cases of Flights 1 and 3 there was a statistically significant reduction in this measurement from P I to P II. No comparable data have been reported in the literature. The U/S ratio showed rather large inter-individual and inter-group variability. For the controls there was a statistically significant reduction in U/S ratio from P I to P II. Again no comparable data have been reported in the literature.

Experimental regimen and serum osmolarity: The detailed data presented in Table III. 32 confirm the average data of Table III. 9. Marked increases in serum osmotic pressure occurred among those men subsisting on diets of high osmotic content and limited water. When the osmotic load was low or the water unlimited, the concentration tended to remain constant.

Experimental regimen and minute urinary osmotic excretion: The calculated values for minute urinary osmotic excretion have been presented in Table III. 33. Marked variations were noted with respect to nutrient regimen but water and work did not materially affect the osmotic output.

Experimental regimen and U/S osmotic ratio: The calculated ratios for the different experimental regimens are summarized in Table III. 34 and Figures III. 18 and 19. With only one exception --- 15/52/33 1000 Hard Work --- the men on limited water maintained a higher U/S ratio than the men on unlimited water. The differences, in general, were greater in the cases of the intermediate and high osmotic regimens than in the low osmotic regimens. The absolute maximum U/S ratio was 4.33 for Subject 36 (2/20/78 1000 L Hard Work). A number of the unlimited water regimens were associated with a marked decrease in the U/S ratio during EXP II: (1) for hard work groups 0/100/0 2000, 2/20/78 2000, and 30/0/70 1000 and (2) for light work groups ST 0, 0/100/0 1000 and 2000, 2/20/78 1000 and 2000, and controls. This reduction was primarily due to the passage of a more dilute urine. The meaning of this drop is not apparent at the present time, but it may have been related to a cold diuresis associated with the episode of cold weather immediately preceding the two-hour test of EXP II.

Serum osmolarity in recovery: The trends in the recovery periods are different for the five groups (Table III. 35). Flights 1 and 2 and the control subjects had significantly higher serum osmolar concentrations in REC II

than in P II. In Flights 3 and 4 the REC II values were not significantly different from P II although the means were somewhat elevated. This trend is remarkable when we recall that concurrently there was a significant reduction in the hematocrit. (See section on Hematology.) It is probable that these trends reflect profound physiological adjustments resulting from (1) rehabilitation from the experimental regimen and (2) change of nutrient intake from packaged rations to garrison rations.

Minute osmolar excretion in recovery: In the recovery periods, there was a marked increase in solute excretion (Table III. 33). The output increased significantly over the pre-period rates in both REC I and REC II (Table III. 36).

Urine/serum osmotic ratios in recovery: In the recovery periods there was a return of the U/S osmotic ratios to pre-period levels (Table III. 34). There were no striking and consistent differences between REC I and REC II.

Relation of Osmotic Load to Water Requirements. Two parameters must be considered in discussing water requirements (Figures III. 20 and 21). The first is the obligatory urine volume at maximal U/S ratio. This parameter defines the condition under which the kidney is performing maximum osmotic work. According to the data collected during the temperate study of 1953 and the present cold weather study (Table III. 37 and Figure III. 22), the obligatory urine volume varies directly as the osmotic load ($r = 0.937$). This relationship can be described by the regression equation

$$L = 1363.46V_o - 17.67 \qquad (1)$$

where L is the osmotic load and V_o, the obligatory volume at the maximal U/S osmotic ratio for the given load. According to this equation 0.75 ml of urine must be produced each minute to excrete each milliosmol of solute.

The second is the isosmotic volume at a U/S ratio of 1.00. This parameter defines the condition under which the kidney performs the least osmotic work. According to the data collected (Table III. 37 and Figure III. 22), the isosmotic volume varies directly with the osmotic load ($r = 0.916$). This relationship can be described by the regression equation

$$L = 272.63V_I + 55.58 \qquad (2)$$

where L is the osmotic load and V_I, the isosmotic volume at the U/S ratio of 1.00 for the given load. According to this equation, 3.46 ml of isotonic urine must be produced each minute to excrete each milliosmol of solute.

These two equations permit definition of the maximum concentrating capacity of the human kidney. At any given osmotic load

$$272.63\ V_I + 55.58 = 1363.46\ V_o - 17.62$$

$$\text{Hence,}\quad \frac{V_I}{V_o} = 5.00 - \frac{0.27}{V_o} \qquad (3)$$

$$\text{or,}\quad \frac{V_I}{V_o} = 5.00\left(\frac{L - 55.58}{L + 17.67}\right) \qquad (4)$$

where V_I/V_o represents the degree to which isotonic urine can be concentrated by the kidney. Accordingly the empirically defined limit to the concentrating ability of the kidney is 5.00. This value is attained as V_o or L become very large.

Another significant implication of equation (4) concerns renal handling of low osmotic loads. As L approaches 55.58, V_I/V_o approaches zero. Since V_o has never been reported as being zero even in extreme dehydration, we would expect that it is V_I which reaches zero with decreasing osmotic load. This interpretation is strongly supported by the observations made during the winter of 1953. It was observed that subjects subsisting on 0/100/0 1000 or 2000 exhibited U/S ratios less than 1.0 with moderately large urine volumes. In other words, the isosmotic volume did, in fact, approach zero.

The U/S ratio has heretofore been used to calculate this maximum concentrating ability. This approach yields erroneous conclusions, for the behavior of S is different depending upon whether the dehydration is acute or chronic. Actually our value of 5.00 lies intermediate between the maximum U/S ratio of Gamble (1947) of 4.1 for acute dehydration and the value of 5.9 observed in 1953 for men undergoing chronic dehydration.

The observations on body water reported above reveal that the relation between osmotic load and body water is not as simple as implied by the work of Gamble (1947). A dehydrated subject subsisting on a low osmotic regimen exhibits a diuretic response to a water load strikingly similar to a normally hydrated subject. This fact raises significant questions. Even though a high carbohydrate regimen reduces the "minimum water requirement" as defined by Gamble, can a subject subsisting on this regimen conserve his water allowance as efficiently as a man living on a regimen providing a higher osmotic load? The facts demonstrate that if he were to drink his allowance in large doses, most of it will be excreted in the urine. Are small portions of the allowance similarly handled?

The observations of the present investigation do not directly yield an answer to the second question. There are suggestive indications that when the water is taken in small portions, it is handled just as well by the subjects on the low osmotic regimens as on the high. For the 0/100/0 regimens the mean L is 191 microosmols/min. From equation (4), we calculate that V_I/V_o is 3.24.

This value indicates that, although small volumes of urine are being passed, the kidney is only concentrating to 65% of its capacity. For the 30/0/70 2000 regimen L is 1074 and V_I/V_o is 4.66. In this case --- and with considerably larger minute urinary volumes --- the kidney is concentrating to 93% of its capacity. These differences suggest that perhaps the urine should be more concentrated in the latter than in the former groups of subjects. Analysis demonstrates that such may not be the case. Since the serum osmolarity remained relatively constant in EXP I and EXP II, the ratio

$$\frac{\text{U/S for men on limited water}}{\text{U/S for men on unlimited water}}$$

can be used as an index of the relative concentration of the urine caused by limitation of water. The data summarized in Table III. 38 demonstrate that the urine was no less concentrated for men on low osmotic regimens than on high osmotic regimens. Wide variations are evident, but the means for the ten nutrient mixtures do not deviate appreciably from the grand mean of 1.89. While this evidence cannot be considered conclusive, it does give the impression that if a restricted water allowance is taken in small portions, the retention is independent of the osmotic load. Perhaps additional studies of the present body of data will clarify these questions which are of great practical importance to the survival of the castaway.

TABLE III. 31

PRE-PERIOD DATA ON URINE-SERUM OSMOLARITY

Groups of Subjects	P I			P II		
	M	s.d.	C.V.	M	s.d.	C.V.
			Serum Osmolarity, mOsm/L			
Flight 1	297	12	4.0	293	10	3.4
Flight 2	302	16	5.3	301	8	2.7
Flight 3	312	12	3.9	303	13	4.4
Flight 4	300	13	4.3	297	13	4.4
Controls	304	15	4.9	305	14	4.6
			Urine Osmotic Excretion, microOsm/min			
Flight 1**	949	258	27.2	692	194	27.0
Flight 2	897	352	39.2	886	269	30.4
Flight 3**	1141	309	27.0	839	220	26.2
Flight 4	754	338	44.8	718	285	39.7
Controls	937	474	50.6	663	250	37.7
			Urine/Serum Osmotic Ratio			
Flight 1	1.70	1.00	58.8	2.04	0.64	31.4
Flight 2	2.90	0.86	29.7	2.56	0.91	35.5
Flight 3	2.43	1.02	41.9	1.82	0.74	40.6
Flight 4	2.78	0.83	29.8	2.34	0.80	34.2
Controls**	3.38	0.64	18.9	2.23	0.90	40.3

**M's significantly different at 1% level by "t" test.

TABLE III. 32

SERUM OSMOLARITY
(mOsm/L)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	287	292	295	298	309	307	295	306	314	310
	L	312	298	321	318	305	297	311	309	304	313
0/100/0	U	293	290	312	309	309	301	300	316	320	306
1000	L	294	304	325	314	309	302	306	301	312	300
0/100/0	U	285	314	317	292	317	310	285	314	314	298
2000	L	305	287	306	292	325	286	322	314	311	298
2/20/78	U	298	287	320	309	274	309	292	325	304	298
1000	L	298	300	314	317	312	300	320	306	322	301
2/20/78	U	302	298	298	314	300	320	306	320	301	301
2000	L	302	322	328	308	309	298	312	309	317	298
15/52/33	U	294	312	306	320	314	301	296	304	330	312
1000	L	301	320	314	312	306	304	346	306	330	309
15/52/33	U	296	298	304	314	320	314	288	322	296	295
2000	L	299	314	322	300	300	298	317	330	325	288
15/52/33	U	308	298	298	301	325	305	298	336	309	309
3000	L	294	344	338	317	320	297	341	336	333	304
30/0/70	U	298	304	298	320	295	308	295	306	306	328
1000	L	295	314	314	314	338	310	304	312	317	301
30/0/70	U	290	293	328	308	306	301	306	309	320	298
2000	L	312	314	320	315	325	300	325	350	317	300
Control	U	304	306	305	310	322	314	295	311	301	327
	L	302	311	317	319	329	298	308	308	305	309

*Mean values for PI and PII.

TABLE III. 33

MINUTE URINARY OSMOTIC EXCRETION
(microOsm/min)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	804	819	449	503	1561	1517	1156	805	539	401	1388	1264
	L	1253	1082	503	477	1009	1500	741	911	537	308	1155	1137
0/100/0	U	1055	675	263	195	1463	1400	1065	859	237	195	2372	1059
1000	L	1600	1047	405	229	1175	826	761	531	308	223	1355	812
0/100/0	U	613	630	328	229	1770	1510	860	561	245	216	1123	675
2000	L	569	660	157	222	1025	965	610	878	177	175	1350	893
2/20/78	U	1333	903	674	529	1800	1620	1510	887	458	523	1550	1202
1000	L	545	1045	393	375	940	1170	721	558	517	504	1533	881
2/20/78	U	949	668	590	910	1515	1667	----	1040	523	527	1522	1217
2000	L	868	906	677	631	1205	816	773	1105	530	617	1710	843
15/52/33	U	608	450	361	398	1728	901	----	953	458	435	1321	1390
1000	L	679	614	463	410	1170	580	1321	583	375	440	1497	725
15/52/33	U	1340	569	853	1133	1915	1575	----	1157	623	871	597	1003
2000	L	895	1310	773	637	913	1140	571	473	717	633	825	674
15/52/33	U	913	519	934	677	1385	1073	605	944	747	755	1510	1370
3000	L	673	687	1109	885	863	749	1485	----	953	863	1127	788
30/0/70	U	814	793	710	687	1605	2050	1471	779	897	777	1663	1081
1000	L	817	689	817	553	1370	1370	440	491	728	685	1163	901
30/0/70	U	955	735	1367	804	1026	1135	1090	574	1347	875	1315	835
2000	L	1067	818	966	963	1555	1590	777	841	1183	1085	1550	843
Control	U	1165	950	783	748	801	918	704	591	736	917	708	675
	L	----	576	776	979	637	543	828	471	864	793	464	485

TABLE III. 34

URINE/SERUM OSMOTIC RATIO

Experimental Regimen		Hard Work Pre*	Exp I	Exp II	Rec I	Rec II	Light Work Pre*	Exp I	Exp II	Rec I	Rec II
ST 0	U	1.61	2.56	2.28	2.57	1.45	2.14	2.58	0.75	2.63	2.28
	L	2.59	3.84	3.65	2.93	2.91	3.02	3.39	1.95	3.07	3.12
0/100/0	U	1.77	2.74	1.89	2.29	1.78	1.81	2.05	0.85	2.67	2.88
1000	L	1.70	3.37	2.13	2.31	2.31	2.76	2.92	2.80	2.45	1.79
0/100/0	U	2.45	2.37	1.57	2.79	3.05	2.15	1.65	1.12	1.49	2.39
2000	L	1.97	3.19	2.46	2.87	3.17	2.43	2.37	1.53	2.67	2.80
2/20/78	U	1.95	1.71	2.26	2.51	2.49	2.02	2.50	1.09	2.95	3.59
1000	L	3.31	4.30	3.26	3.70	2.90	2.77	3.23	2.79	2.41	2.57
2/20/78	U	2.52	2.56	1.28	2.43	3.07	1.49	1.82	0.80	1.45	1.42
2000	L	2.71	3.01	2.41	2.70	1.56	2.59	3.53	3.57	1.62	1.99
15/52/33	U	1.92	3.45	2.77	2.38	0.97	1.52	1.75	0.97	3.17	2.10
1000	L	2.00	3.05	2.90	2.18	1.97	1.81	3.53	2.47	1.79	1.76
15/52/33	U	1.74	1.65	1.42	1.67	1.60	1.56	2.73	1.72	2.11	2.07
2000	L	2.54	3.19	2.89	1.94	1.75	2.03	3.74	3.79	1.41	1.49
15/52/33	U	1.20	0.82	1.69	1.11	1.53	2.45	3.29	2.50	3.07	1.90
3000	L	3.68	3.55	3.79	3.09	2.91	2.61	3.65	3.95	1.04	1.24
30/0/70	U	2.05	1.08	1.03	2.93	2.03	3.30	2.52	2.54	2.51	2.45
1000	L	2.56	3.59	2.55	2.73	2.61	3.11	4.21	4.05	2.05	2.49
30/0/70	U	2.64	3.01	2.87	2.78	2.01	1.33	1.57	1.67	3.06	3.25
2000	L	3.28	3.96	3.29	2.09	2.17	1.91	3.43	3.25	1.47	1.67
Control	U	3.19	3.08	2.80	2.50	2.11	2.66	3.23	1.26	2.54	2.47
	L	1.81	2.09	1.78	2.56	2.63	2.57	2.26	0.66	2.85	1.83

*Mean values for PI and PII.

TABLE III. 35

STATISTICAL ANALYSIS OF INCREASE IN SERUM OSMOLARITY IN THE SECOND WEEK OF RECOVERY

A. SERUM OSMOLARITY IN REC II

Groups of Subjects	M mOsm/l	s.d. mOsm/l	C.V. %
Flight 1	307	18	5.9
Flight 2	314	13	4.1
Flight 3	305	11	3.6
Flight 4	300	8	2.7
Controls	323	18	5.6

B. STATISTICAL ANALYSIS: P II vs REC II

Groups of Subjects	"t"	P
Flight 1	3.20	< 0.01
Flight 2	3.95	< 0.01
Flight 3	----	----
Flight 4	----	----
Controls	2.56	0.05

TABLE III. 36

MINUTE URINARY OSMOTIC EXCRETION:
PRE-PERIODS vs. RECOVERY PERIODS

A. FREQUENCY DISTRIBUTION

Class Intervals μ-osm/min	Frequency, % PI+II	REC I	REC II
0-199	0.0	0.0	0.0
200-399	2.8	2.3	1.3
400-599	17.4	1.1	3.5
600-799	31.2	5.7	14.1
800-999	24.3	9.2	25.9
1000-1199	12.5	18.4	14.1
1200-1399	5.6	14.9	16.4
1400-1599	3.5	19.6	15.3
1600-1799	1.4	16.1	2.4
1800-1999	1.4	6.9	4.7
2000-2199	0.0	2.3	0.0
2200-2399	0.0	1.1	2.4
2400-2599	0.0	1.0	0.0
2600-2799	0.0	0.0	0.0
2800-2999	0.0	0.0	0.0
3000-3199	0.0	1.1	0.0
Total	100.1	99.7	100.1

B. STATISTICAL ANALYSIS

Test	d.f.	X^2	P
REC I vs. REC II	12	25.53	0.015
PI+II vs. REC I	12	84.69	< 0.01
PI+II vs. REC II	9	59.91	< 0.01

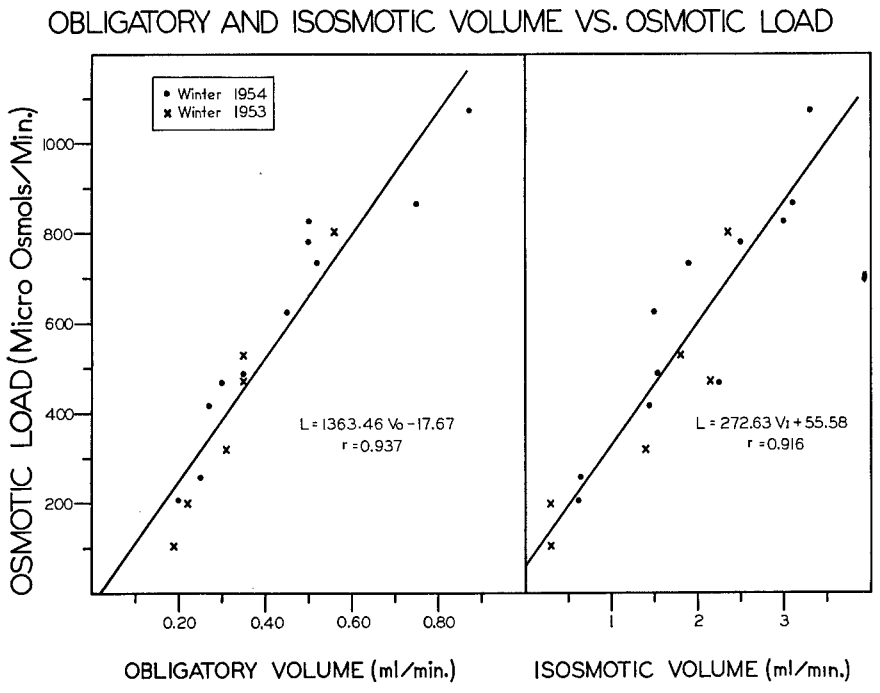


FIGURE III. 18. OSMOTIC URINE/SERUM RATIO, HARD WORK, WINTER, 1954.

TABLE III. 37

EXPERIMENTAL DATA ON OSMOTIC LOAD (L), OBLIGATORY URINARY VOLUME (V_o), AND ISOSMOTIC URINARY VOLUME (V_I)*

Experimental Regimen	Temperate Study Winter, 1953			Cold Weather Study Winter, 1954		
	L	V_o	V_I	L	V_o	V_I
ST O	472	0.35	2.15	468	0.30	2.25
0/100/0 1000	198	0.22	0.31	257	0.25	0.65
0/100/0 2000	104	0.19	0.31	205	0.20	0.62
2/20/78 1000	---	----	----	488	0.35	1.55
2/20/78 2000	---	----	----	625	0.45	1.50
15/52/33 1000	320	0.31	1.39	417	0.27	1.45
15/52/33 2000	528	0.35	1.80	780	0.50	2.50
15/52/33 3000	803	0.56	2.36	866	0.75	3.10
30/0/70 1000	---	----	----	732	0.52	1.90
30/0/70 2000	---	----	----	1074	0.87	3.30
Control	---	----	----	825	0.50	3.00

*Definition of terms and units in text.

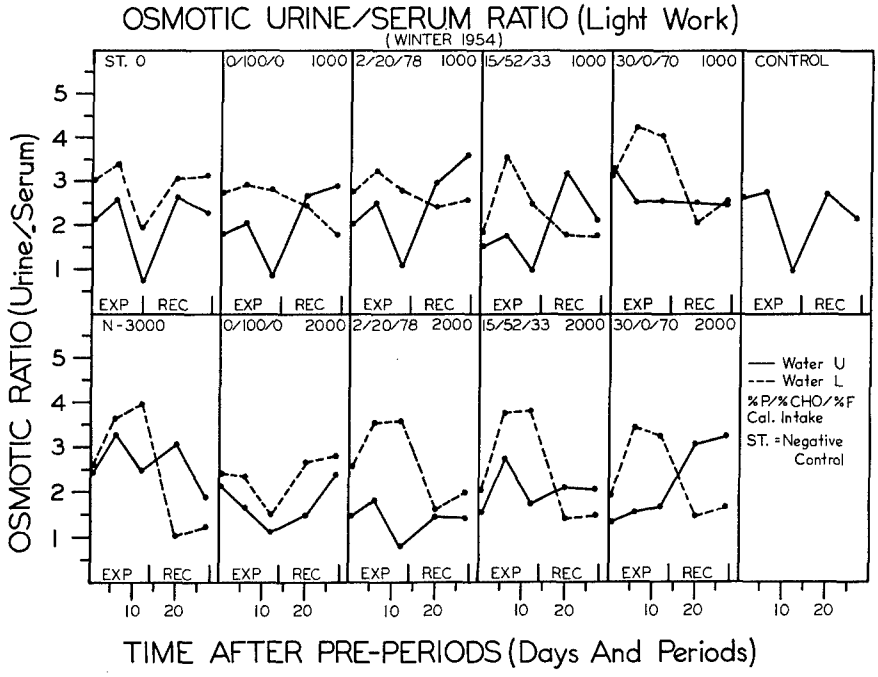


FIGURE III. 19. OSMOTIC URINE/SERUM RATIO, LIGHT WORK, WINTER, 1954.

TABLE III. 38

URINARY CONCENTRATION INDEX VS. EXPERIMENTAL REGIMEN*

Experimental Regimen		Hard Work		Light Work		
		EXP I	EXP II	EXP I	EXP II	Mean
ST 0		1.50	1.60	1.31	2.60	1.75
0/100/0	1000	1.23	1.13	1.43	3.30	1.77
0/100/0	2000	1.35	1.57	1.44	1.37	1.43
2/20/78	1000	2.52	1.44	1.29	2.56	1.95
2/20/78	2000	1.18	1.88	1.94	4.46	2.36
15/52/33	1000	0.89	1.05	2.65	2.54	1.78
15/52/33	2000	1.93	2.04	1.37	1.04	1.60
15/52/33	3000	4.32	2.24	1.11	1.58	2.31
30/0/70	1000	3.32	2.48	1.67	1.59	2.26
30/0/70	2000	1.32	1.19	2.18	1.95	1.66

*Concentration index defined in text.

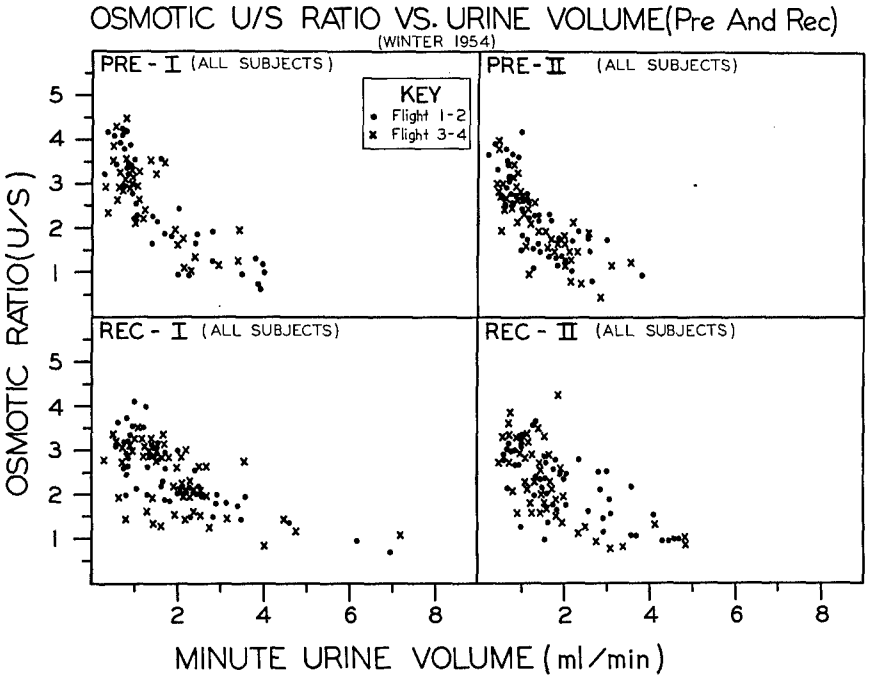


FIGURE III. 20

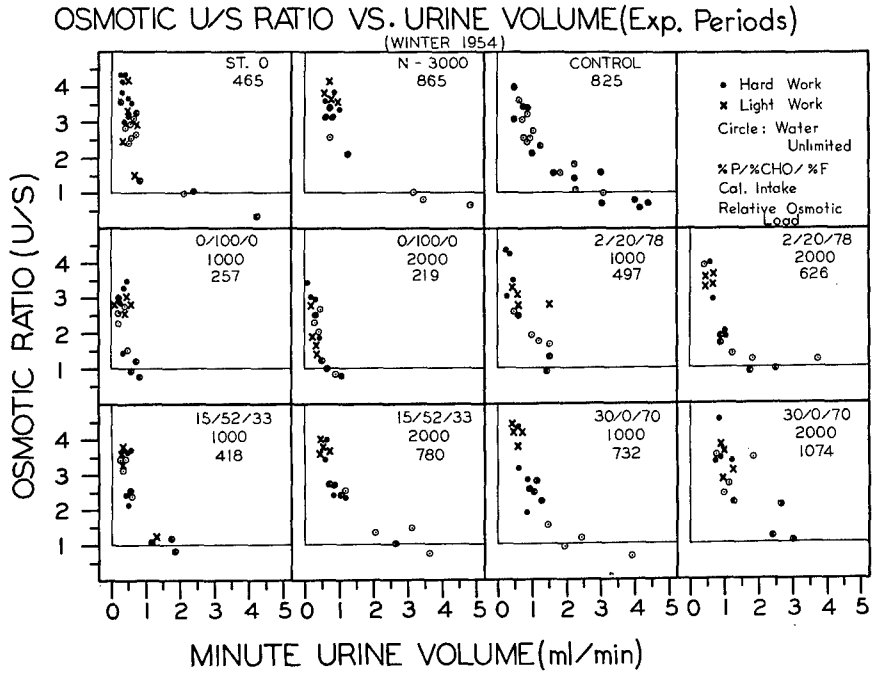


FIGURE III. 21

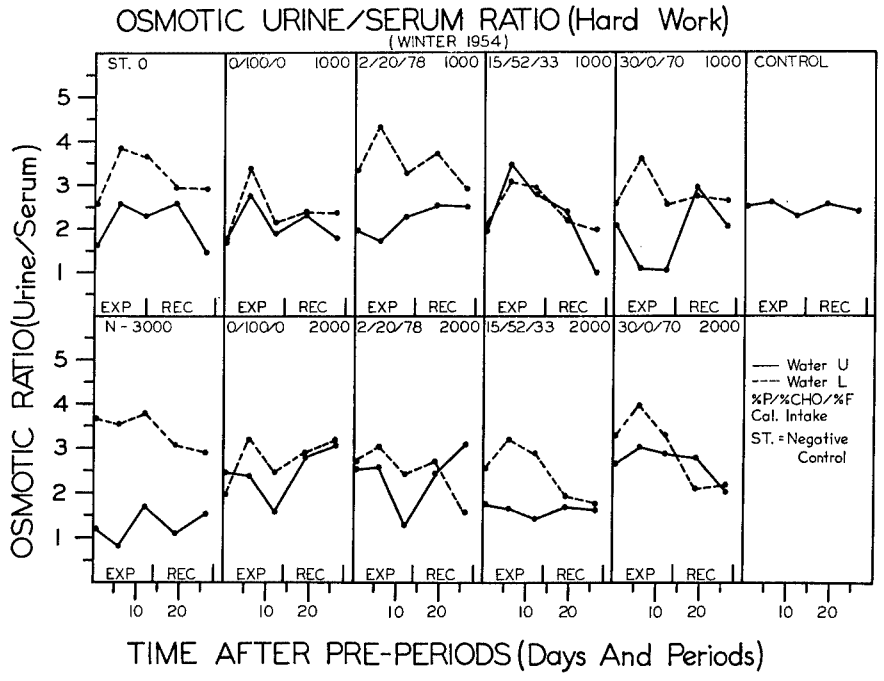


FIGURE III. 22. OBLIGATORY AND ISOSMOTIC VOLUME VS. OSMOTIC LOAD.

4. Renal Clearance

Renal clearance is defined as C = uxv/s, where C is clearance in ml/min, U is urinary concentration and S, serum concentration (both concentrations expressed in the same units (e.g., mg/ml)), and V is minute urine volume in ml/min. In the present investigation two clearances were calculated: osmotic clearance and creatinine clearance.

Osmotic Clearance. The osmotic clearance (C_{osm}) represents the volume of serum cleared of solutes per minute. The pre-period data for osmotic clearance are summarized in Table III. 39. C_{osm} is of the order of 2 - 3 ml/min. Flights 1 and 3 show a statistically significantly decrease from P I to P II.

The variation in the clearance with the experimental regimen is shown in Table III. 40. C_{osm} is independent of the water regimen and tends to vary directly with the osmotic load.

Creatinine Clearance. The creatinine clearance was calculated from data on serum creatinine and minute urinary excretion of creatinine. Before considering the changes in the clearance per se, the basic data must be discussed.

Serum creatinine: Table III. 41 gives the pre-period observations on serum creatinine. These data represent serum creatinine and not total serum chromogen as was measured in the winter of 1953. The values are in excellent agreement with those reported by Haugen and Blegen (1953).

The changes observed in serum creatinine during the experimental and recovery periods have been summarized in Table III. 42. Significant deviations from the pre-period values occurred only in the experimental periods; in the case of the controls, the serum creatinine remained remarkably constant through the six-week period. Large increases in serum creatinine were limited to the diets containing 15 and 30% of the calories from protein, and the magnitude of the rise was greater for men on restricted water than for men on unrestricted water. There were lesser rises in the cases of the low protein regimens and again limitation of water accentuated the trend. There were no appreciable differences in the variations of serum creatinine among men engaged in hard work as compared with men performing light work.

Minute excretion of creatinine: The mean minute excretions of creatinine for the five groups of subjects were, for the most part, close to values reported in the literature (Sargent et al., 1954) (Table III. 43). Only Flight 1 showed a significant decrease from P I to P II. A large decrease was found for the control subjects but it was not significant due to the large standard deviation for P I.

The observations for the several weeks of the trial are summarized in Table III. 44. No consistent and significant trends are evident except in the case of ST 0, 0/100/0 1000, and 30/0/70 regimens. Subjects on starvation and pure carbohydrate exhibited a decrease in the creatinine output. This reduction was most marked in EXP I. Men on the meat bar regimen excreted creatinine at a substantially higher rate than in the pre-period, and this higher rate was most noteworthy for men subsisting on the 2000-Calorie regimen. Work and limitation of water did not substantially modify the rate of creatinine excretion.

Creatinine clearance: The mean creatinine clearance for P I and P II for all 99 subjects was 157 ± 45 ml/min (Table III. 45A). This value is somewhat higher than the clearance measured during the winter of 1953. The higher value resulted from the use of a different method of measuring serum creatinine (vide supra). An analysis of the frequency distribution indicated that 80.1% of values fell within the range 100 to 200 ml/min (i.e., 157 ± 45). Because of the erratic data at the ends of the frequency distribution (Table III. 45B), we have used the grand mean rather than the individual subject's pre-period value as the standard of reference for evaluating the effects of the experimental regimens. These erratic values probably arose from renal and dietary influences discussed fully in Section II. Inspection of the data summarized in Table III. 46 and Figures III. 23 and 24 will demonstrate that, in general, this standard did not differ significantly from the actual observed pre-period means.

The effects of the several experimental regimens on the creatinine clearance are qualitatively reminiscent of the results of the study of 1953. During

the experimental periods the clearance decreased 55-65% and then tended to return to control levels during the recovery periods. The reduction of clearance tended to be greater on the 1000-Calorie regimens than on the 2000-Calorie regimens. In general, the least changes were observed on the 15/52/33 rations. Limitation of water did not consistently alter the clearance. Work per se likewise did not modify the resting clearance.

The 1954 observations, however, differ from the 1953 data in two significant respects. (1) In 1953 the clearance remained low in EXP II. In 1954, it rose toward control levels. (2) The "clearance curve" tended to discriminate between experimental regimens in 1953. In 1954 the data strongly imply that this test of renal function is non-discriminatory; that is, the trends represent a non-specific reaction to the total stress situation of the experimental period. This generalization is supported by comparison of the ST 0 regimen with the N 3000 (15/52/33 3000) and control regimens. Closely similar variations are evident; they differ only in magnitude. This conclusion is supported by the literature (Smith, 1951): exercise, heat, and anoxia each tend to decrease renal clearance of creatinine and inulin. If the reduced clearance we observed is a non-specific reaction, it may be then that the tendency to return to control levels in EXP II is an adaptation.

Analysis of the data on creatinine clearance indicates that in the experimental periods there was a significant general decrease. The reduction of clearance was independent of work and water intake; it was greater in EXP I than in EXP II (Table III. 47). Since the altered renal function was a general reaction, it was decided that the X^2 test would be appropriate for testing the significance of the reduction. Like the mean values, the frequency distributions revealed a sharp shift to lower levels in the experimental periods: in EXP I 74.3% of the clearances fell between 76 and 125 ml/min; in EXP II 75.6% of the clearances were in the range 101-175 ml/min (Table III. 48A). These facts indicate a concurrent reduction in inter-individual variability which would be expected if a general reaction to the stress of the field phase were occurring. The reduction in EXP I was highly significant ($P < 0.001$); that in EXP II was significant at the 2% level (Table III. 48B). This latter result supports the idea of return of clearances toward pre-period values. In the recovery periods the mean clearances were quite similar to those for the pre-period (Table III. 46).

One can only speculate on the mechanism of this reduction. The fact that there were concurrent changes in the urinary sediment (casts and red cells) and albuminuria in the experimental periods suggests that reduced renal blood flow may have taken place with hypoxic damage to renal glomerular membrane. That environmental stress may reduce renal blood flow has been demonstrated by several investigators (Smith, 1951). Filtration rate was most markedly reduced in EXP I; changes in urinary sediment in EXP II. A concurrence need not be expected, but the long time lag more likely than not reflects a condition of the trial; viz., the impossibility of testing such a large group of subjects at more frequent intervals. If the reduction in filtration rate is indeed a non-specific reaction, it would behoove one to more precisely examine the nature of altered renal function. The implications for the castaway's survival should be thoroughly explored.

TABLE III. 39

PRE-PERIOD DATA ON OSMOLAR CLEARANCE
(ml/min)

Groups of Subjects	P I			P II		
	M	s.d.	C.V.	M	s.d.	C.V.
Flight 1**	3.20	0.86	26.9	2.41	0.69	28.6
Flight 2	2.95	1.08	36.6	3.01	0.97	32.2
Flight 3**	3.65	0.92	25.2	2.72	0.68	25.0
Flight 4	2.51	1.18	46.9	2.49	0.96	38.5
Controls	3.09	1.51	48.9	2.17	0.81	37.3

**M's significantly different at 1% level by "t" test.

TABLE III. 40

OSMOTIC CLEARANCE
(ml/min)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	2.77	2.90	1.55	1.69	5.18	4.91	3.58	2.43	1.83	1.31	5.54	4.06
	L	5.99	3.49	1.69	1.49	3.19	4.90	2.48	3.11	1.72	1.00	4.98	3.60
0/100/0	U	3.59	2.33	0.91	0.57	4.73	4.53	3.56	2.88	0.82	0.62	7.45	3.46
1000	L	5.40	4.51	1.33	0.71	3.75	2.66	2.53	1.74	0.98	0.74	4.34	2.70
0/100/0	U	2.12	2.31	1.05	0.71	6.05	4.77	2.76	1.84	0.86	0.69	3.54	2.27
2000	L	1.84	2.24	0.55	0.72	3.51	2.97	2.10	3.10	0.55	0.56	4.43	3.00
2/20/78	U	4.40	3.08	2.35	1.66	5.79	6.04	4.70	2.91	1.55	1.61	5.14	4.02
1000	L	1.87	3.38	1.31	1.20	3.00	3.75	3.36	1.91	1.62	1.65	4.84	2.92
2/20/78	U	3.35	2.23	1.99	3.06	4.84	5.58	----	3.17	1.68	1.65	4.82	4.10
2000	L	2.87	3.01	2.09	1.92	3.72	2.64	2.54	3.72	1.70	2.00	5.38	2.84
15/52/33	U	2.13	1.52	1.14	1.29	5.39	2.88	----	3.14	1.55	1.44	4.00	4.48
1000	L	2.22	2.09	1.96	1.32	3.76	1.09	----	1.97	1.08	1.43	4.54	2.34
15/52/33	U	4.54	1.91	2.81	3.74	6.04	4.97	----	3.67	2.16	2.70	1.00	3.40
2000	L	3.42	4.52	2.45	1.98	3.04	3.81	1.96	1.57	2.28	1.92	2.53	2.36
15/52/33	U	2.99	1.71	3.13	2.27	4.59	3.30	2.12	3.20	2.50	2.25	4.88	4.43
3000	L	2.37	2.33	3.23	2.62	2.72	2.35	5.18	----	2.80	2.57	3.38	2.59
30/0/70	U	2.81	2.59	2.33	2.30	5.02	6.79	4.66	2.62	3.04	2.54	5.44	3.31
1000	L	2.81	2.29	2.61	1.77	4.34	4.05	1.44	1.57	2.40	2.20	3.65	2.99
30/0/70	U	3.30	2.53	4.61	2.45	3.28	3.71	3.52	1.94	4.38	2.84	4.10	2.80
2000	L	3.35	2.67	3.09	3.01	4.94	4.89	2.54	2.88	3.64	3.11	4.96	2.80
Control	U	3.81	3.13	2.55	2.45	2.60	2.90	2.28	1.83	2.48	2.94	2.38	2.19
	L	----	1.98	2.50	3.09	2.00	1.66	2.82	1.53	2.81	2.55	1.53	1.58

TABLE III. 41

PRE-PERIOD DATA FOR SERUM CREATININE
(mg/100 ml)

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
Flight 1	0.93	0.11	11.8	0.81	0.15	18.5
Flight 2	0.92	0.08	8.7	0.94	0.10	10.6
Flight 3	0.82	0.09	11.0	0.77	0.10	13.0
Flight 4	0.87	0.12	13.8	0.75	0.10	13.3
Controls	0.90	0.11	12.2	0.82	0.09	11.0

TABLE III. 42

SERUM CREATININE
(mg/100 ml)

Experimental Regimen		Hard Work Pre*	Exp I	Exp II	Rec I	Rec II	Light Work Pre*	Exp I	Exp II	Rec I	Rec II
ST 0	U	0.83	0.99	0.97	0.94	0.74	0.80	1.10	0.95	0.85	0.68
	L	0.91	1.11	1.12	0.83	0.84	0.87	1.09	1.06	1.06	0.86
0/100/0	U	0.74	1.06	0.82	0.90	0.68	0.75	1.16	1.09	0.96	0.68
1000	L	0.96	1.23	1.18	0.85	0.94	0.76	1.18	1.11	0.90	0.74
0/100/0	U	0.95	1.18	1.14	0.79	0.82	0.81	1.16	1.00	0.88	0.74
2000	L	0.94	1.11	1.04	0.76	0.90	0.88	1.22	0.97	1.18	0.92
2/20/78	U	0.97	1.04	0.80	0.85	0.88	0.71	1.04	1.00	0.84	0.63
1000	L	0.92	1.04	1.02	0.73	0.85	0.78	1.30	0.76	1.05	0.83
2/20/78	U	0.90	0.90	0.80	0.70	0.70	0.83	1.01	0.98	0.84	0.79
2000	L	0.97	1.11	1.02	0.76	0.83	0.83	1.32	1.02	0.82	0.84
15/52/33	U	0.91	0.97	0.90	0.72	0.66	0.79	1.06	1.02	0.92	0.68
1000	L	0.97	1.08	1.14	0.88	0.98	0.76	1.32	1.00	0.97	0.84
15/52/33	U	0.82	1.13	1.02	0.78	0.73	0.90	1.18	1.22	0.95	0.92
2000	L	0.81	1.20	1.14	0.68	0.76	0.81	1.46	1.12	1.02	0.88
15/52/33	U	0.93	1.35	1.09	0.86	0.78	0.83	1.18	1.14	0.86	0.72
3000	L	0.92	1.29	1.18	0.85	0.90	0.82	1.67	1.16	1.09	0.90
30/0/70	U	0.82	1.12	1.02	0.78	0.70	0.74	1.18	1.08	0.83	0.66
1000	L	0.97	1.50	1.31	0.82	0.85	0.85	1.56	1.08	1.13	0.98
30/0/70	U	0.94	1.50	1.30	0.88	0.88	0.86	1.54	1.30	0.98	0.79
2000	L	0.88	1.54	1.45	0.79	0.79	0.70	1.72	1.50	0.91	0.76
Control	U	0.90	1.00	0.75	0.79	0.90	0.84	0.95	0.90	0.94	0.82
	L	0.95	1.00	0.84	0.79	1.00	0.77	0.92	0.72	0.92	0.98

*Mean values for PI and PII.

TABLE III. 43

PRE-PERIOD DATA ON MINUTE EXCRETION OF CREATININE
(mg/min)

Groups of Subjects	P I			P II		
	M	s.d.	C.V.	M	s.d.	C.V.
Flight 1**	1.34	0.37	27.6	0.93	0.26	28.0
Flight 2	1.54	0.39	25.3	1.41	0.36	25.5
Flight 3	1.43	0.20	14.0	1.25	0.29	23.8
Flight 4	1.37	0.21	15.3	1.34	0.42	31.3
Controls	1.78	0.80	44.9	1.12	0.24	21.4

**M's significantly different at 1% level.

TABLE III. 44

MINUTE EXCRETION OF CREATININE
(mg/min)

Experimental Regimen		Hard Work					Light Work				
		Pre*	Exp		Rec		Pre*	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	1.21	0.96	1.46	1.38	1.24	1.38	1.11	1.27	1.39	1.18
	L	1.49	1.13	1.34	1.40	1.40	1.59	1.04	1.10	1.48	1.22
0/100/0	U	1.06	0.97	0.98	1.08	1.02	1.30	1.12	1.06	2.24	1.12
1000	L	1.95	1.54	1.50	1.26	1.33	1.22	1.14	1.18	1.34	1.05
0/100/0	U	0.92	1.50	1.28	1.12	1.10	1.18	1.28	1.40	1.34	0.84
2000	L	1.31	0.93	1.30	1.30	1.38	1.32	1.04	1.44	1.61	1.24
2/20/78	U	1.37	1.46	1.19	1.27	1.43	1.32	1.24	1.18	1.32	1.29
1000	L	1.31	0.76	0.84	1.38	1.44	1.24	1.24	1.21	1.66	1.22
2/20/78	U	1.16	1.02	1.37	1.12	1.54	1.34	1.28	1.09	1.01	1.54
2000	L	1.52	1.38	1.26	1.61	1.24	1.52	1.22	1.47	1.54	1.21
15/52/33	U	0.96	0.91	0.97	1.10	0.86	1.12	1.02	0.99	1.34	1.26
1000	L	1.31	1.30	1.12	1.44	1.26	1.25	1.07	1.32	1.75	1.21
15/52/33	U	1.07	1.54	1.76	1.38	1.26	1.52	1.84	1.68	0.42	1.52
2000	L	1.40	1.58	1.31	1.26	1.51	1.22	1.64	1.54	1.37	1.15
15/52/33	U	0.78	1.42	1.57	1.50	0.94	1.55	1.55	1.61	1.45	1.50
3000	L	1.44	1.84	1.64	1.58	1.54	1.70	1.80	1.90	1.58	1.26
30/0/70	U	1.54	1.02	1.10	1.12	1.13	1.58	1.70	1.64	1.50	1.24
1000	L	1.30	1.70	1.48	1.31	1.54	1.14	1.51	1.52	1.33	1.16
30/0/70	U	1.26	2.93	1.74	1.36	0.98	1.11	2.58	1.91	1.52	1.12
2000	L	1.73	1.93	1.67	1.36	1.08	1.26	2.19	2.06	1.30	1.06
Control	U	1.51	1.15	1.30	1.28	1.28	1.26	1.30	1.59	1.17	1.09
	L	1.52	1.21	1.29	1.06	1.41	1.50	1.51	1.39	1.24	1.02

*Mean values for PI and PII.

TABLE III. 45

PRE-PERIOD DATA ON CREATININE CLEARANCE

A. PRE-PERIOD MEANS

Groups of Subjects	Creatinine Clearance, ml/min		
	P I	P II	P I + P II
Flight 1	142	121	129
Flight 2	170	153	162
Flight 3	182	159	168
Flight 4	160	174	166
Controls	197	133	158

Weighted Mean = 157 ± 45

B. FREQUENCY DISTRIBUTION OF CLEARANCES: P I AND P II*

Class Intervals	Frequency No.	Distribution %
51-75	5	3.1
76-100	10	6.2
101-125	20	12.4
126-150	35	21.7
151-175	47	29.2
176-200	27	16.8
201-225	9	5.6
226-250	2	1.2
251-275	2	1.2
276-300	1	0.6
301-325	1	0.6
326-350	0	0.0
351-375	2	1.2
Total	161	99.8

*P I vs. P II: $X^2 = 13.72$ P = 0.30

TABLE III. 46

RENAL FUNCTION: CREATININE CLEARANCE
(ml/min)

Experimental Regimen		Hard Work						Light Work					
		Pre*		Exp		Rec		Pre*		Exp		Rec	
		Obs.	Std.	I	II	I	II	Obs.	Std.	I	II	I	II
ST 0	U	155	157	97	146	151	167	172	157	101	128	164	202
	L	169	157	104	121	170	149	192	157	96	103	138	140
0/100/0	U	136	157	92	120	120	150	172	157	96	98	228	164
1000	L	217	157	86	128	148	144	162	157	98	106	149	141
0/100/0	U	97	157	88	114	146	138	142	157	109	140	154	115
2000	L	140	157	86	126	170	154	151	157	86	148	137	134
2/20/78	U	144	157	142	137	150	162	181	157	124	116	164	205
1000	L	140	157	75	84	190	170	161	157	96	158	158	145
2/20/78	U	134	157	114	172	139	220	156	157	126	111	137	160
2000	L	157	157	124	124	212	148	192	157	94	145	186	149
15/52/33	U	93	157	122	108	156	128	110	157	96	98	147	188
1000	L	136	157	131	100	169	130	181	157	81	132	181	141
15/52/33	U	115	157	136	172	176	172	176	157	156	138	44	165
2000	L	174	157	133	116	184	198	149	157	110	140	134	132
15/52/33	U	83	157	105	144	174	120	178	157	132	145	174	214
3000	L	157	157	145	140	186	170	172	157	108	164	144	141
30/0/70	U	186	157	92	108	142	161	215	157	146	151	180	188
1000	L	134	157	114	113	162	182	135	157	98	140	118	120
30/0/70	U	136	157	190	134	156	110	146	157	102	146	156	144
2000	L	205	157	126	116	172	137	180	157	127	140	146	140
Control	U	164	157	116	175	161	144	134	157	129	177	125	136
	L	144	157	121	156	135	141	188	157	164	194	136	104

*Mean values for PI and PII.

TABLE III. 47

NON-SPECIFIC REACTION PATTERNS FOR CREATININE CLEARANCE
(ml/min)

Periods	Hard Work			Light Work		
	U	L	M*	U	L	M*
PRE (std.)	157	157	157	157	157	157
EXP I	112	117	115	118	100	116
EXP II	139	122	137	131	136	144
REC I	155	177	162	160	146	149
REC II	149	158	152	187	139	155

*M includes data from U and L groups plus the controls.

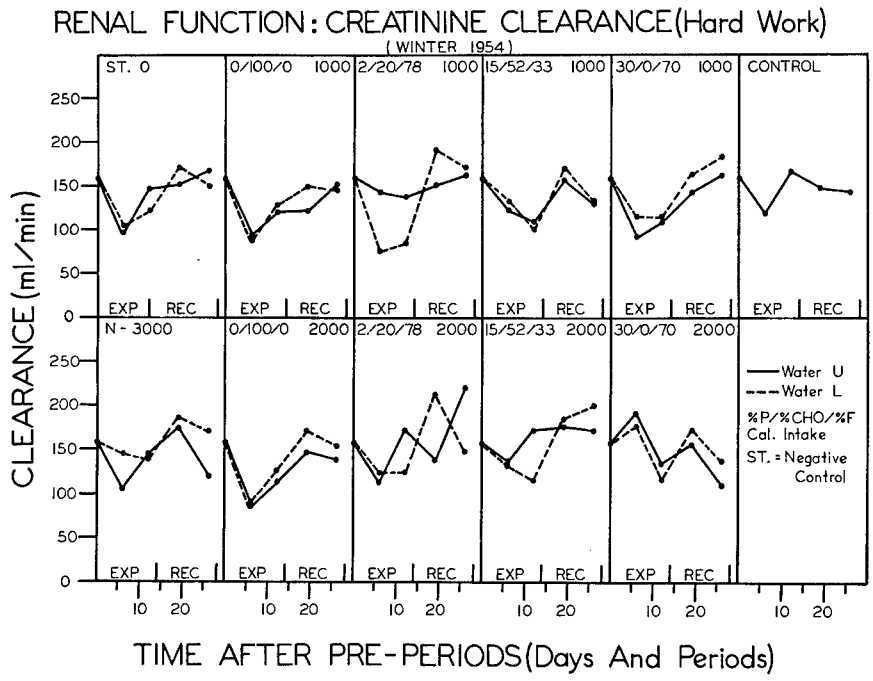


FIGURE III. 23. RENAL FUNCTION: CREATININE CLEARANCE (HARD WORK), WINTER, 1954.

TABLE III. 48

ANALYSIS OF NON-SPECIFIC REACTION PATTERN OF CREATININE CLEARANCE

A. FREQUENCY DISTRIBUTION

Class Intervals	Exp I		Exp II	
ml/min	No.	%	No.	%
51-75	2	2.2	1	1.1
76-100	31	33.4	12	12.8
101-125	38	40.9	26	27.7
126-150	15	16.1	26	27.7
151-175	4	4.3	19	20.2
176-200	2	2.2	8	8.5
201-225	0	0.0	2	2.1
226-250	1	1.1	0	0.0
Total	93	100.2	94	100.1

B. STATISTICAL ANALYSIS

Test	X^2	P
Pre I & II vs. Exp I	87.03	< 0.001
Pre I & II vs. Exp II	24.44	< 0.02

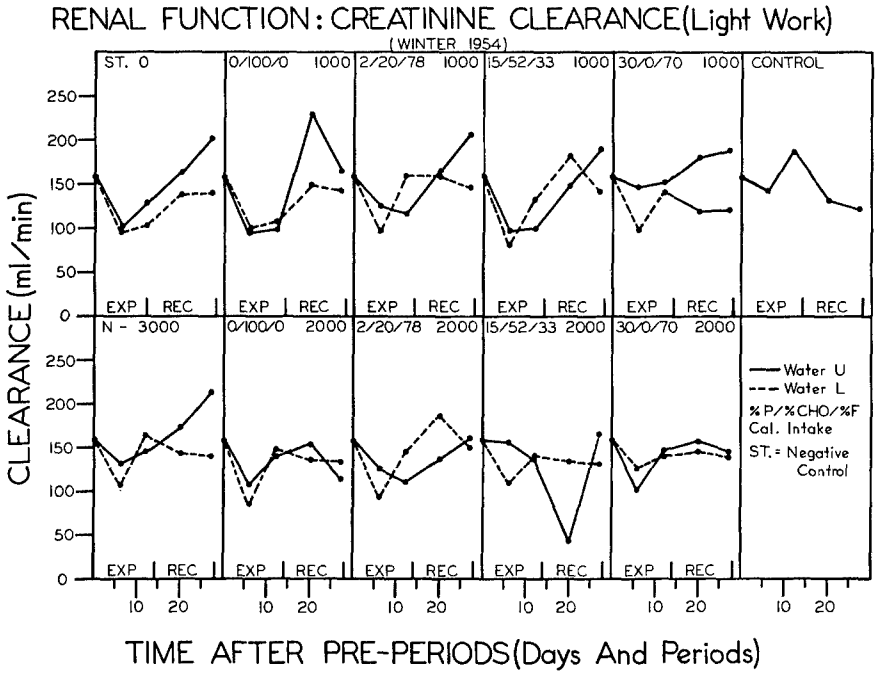


FIGURE III. 24. RENAL FUNCTION: CREATININE CLEARANCE (LIGHT WORK), WINTER, 1954.

3. Serum Non-Protein Nitrogen

In the present investigation the serum N.P.N. was measured rather than the serum urea N. The pre-period data were entirely within normal limits and reveal only small inter- and intra-group variability (Table III. 49). The two pre-periods for Flight 1 were significantly different by the "t" test and may reflect the larger intake of protein in P II.

The variations in serum N.P.N. from period to period are illustrated in Figures III. 25 and 26. The data from which these figures were prepared are given in Table III. 50. In general the fluctuations are reminiscent of those described for serum creatinine, and of those reported for serum urea N (Sargent et al., 1954). The trends depicted are largely conditioned by water intake and nutrient mixture. Work load has a secondary but very significant effect. Since the controls exhibited no variations we can assume that exposure to cold was not a significant variable.

Study of the figures indicates that the threshold for azotemia is controlled by (1) protein intake, (2) water intake, and (3) caloric balance. Although the threshold can not be precisely defined in terms of the available data, the correlations are convincing and consistent with modern ideas of

renal physiology. Regardless of water intake or work load, the 30/0/70 regimen causes marked azotemia. When the intake of protein is isocalorically reduced from 30% to 15% of total calories, no azotemia occurs in the man supplied with adequate water. If the supply of water is limited, azotemia rapidly develops when hard work is required. Little azotemia, however, appears in the sedentary castaway. When the intake of protein is further reduced to 2%, the only condition provoking azotemia is limitation of water and hard work. On the 0/100/0 regimens there is a tendency for the N.P.N. to fall rather than rise. Starvation with its concurrent catabolism of body tissues is associated with an increased N.P.N. under all of the conditions tested. The stepwise reduction in the threshold for azotemia clearly demonstrates the stressful nature of the hard work regimen and the role of limitation of water in accentuating an azotemia.

In REC II the azotemia disappeared but in some instances the serum N.P.N. remained above pre-period values. This phenomenon was probably the consequence of the large intake of protein during this period.

TABLE III. 49

PRE-PERIOD DATA ON SERUM NON-PROTEIN NITROGEN
(mg/100 ml)

Groups of Subjects	P I			P II		
	M	s.d.	C.V.	M	s.d.	C.V.
Flight 1**	28	3	10.7	31	3	9.7
Flight 2	28	3	10.7	29	3	10.4
Flight 3	29	2	6.9	29	3	10.4
Flight 4	30	2	6.7	30	3	10.0
Controls	30	2	6.7	32	3	9.4

**Means significant at 1% level by "t" test.

TABLE III. 50

SERUM NON-PROTEIN NITROGEN
(mg/100 ml)

Experimental Regimen		Hard Work					Light Work				
		Pre*	Exp		Rec		Pre*	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	28	30	32	32	33	28	29	30	30	29
	L	29	34	38	32	32	30	32	35	32	38
0/100/0	U	30	30	24	30	38	29	30	27	27	32
1000	L	29	30	27	29	34	29	31	32	30	34
0/100/0	U	29	30	24	26	39	29	28	24	27	36
2000	L	29	24	26	28	36	30	25	24	30	35
2/20/78	U	28	26	25	32	35	29	26	28	30	30
1000	L	26	36	35	34	33	28	26	26	31	34
2/20/78	U	29	28	24	30	34	29	28	26	32	31
2000	L	27	25	36	31	28	30	30	28	31	32
15/52/33	U	31	34	26	30	36	28	30	30	33	32
1000	L	30	36	38	32	30	30	34	32	31	32
15/52/33	U	26	30	27	29	38	30	26	31	34	34
2000	L	29	32	38	29	26	28	34	34	30	32
15/52/33	U	31	31	28	32	34	27	30	30	32	36
3000	L	31	38	48	34	32	31	38	35	30	33
30/0/70	U	30	30	32	32	42	31	30	36	35	32
1000	L	28	44	46	38	36	31	41	52	36	38
30/0/70	U	32	44	36	32	40	29	40	44	34	28
2000	L	29	52	50	40	38	31	42	51	34	32
Control	U	32	33	29	32	29	30	28	28	30	29
	L	30	29	31	31	32	32	31	29	31	32

*Mean values for PI and PII.

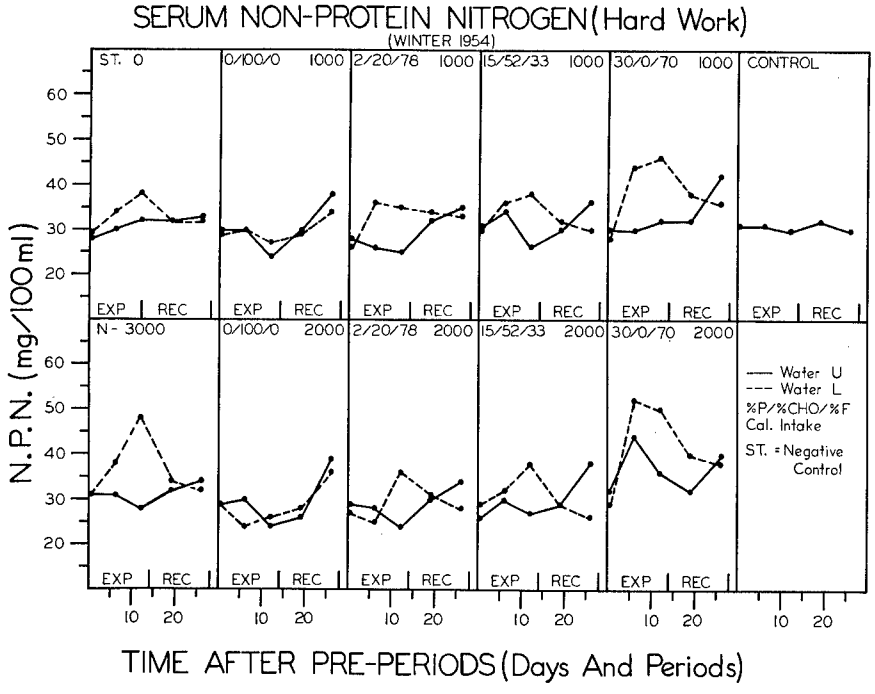


FIGURE III. 25

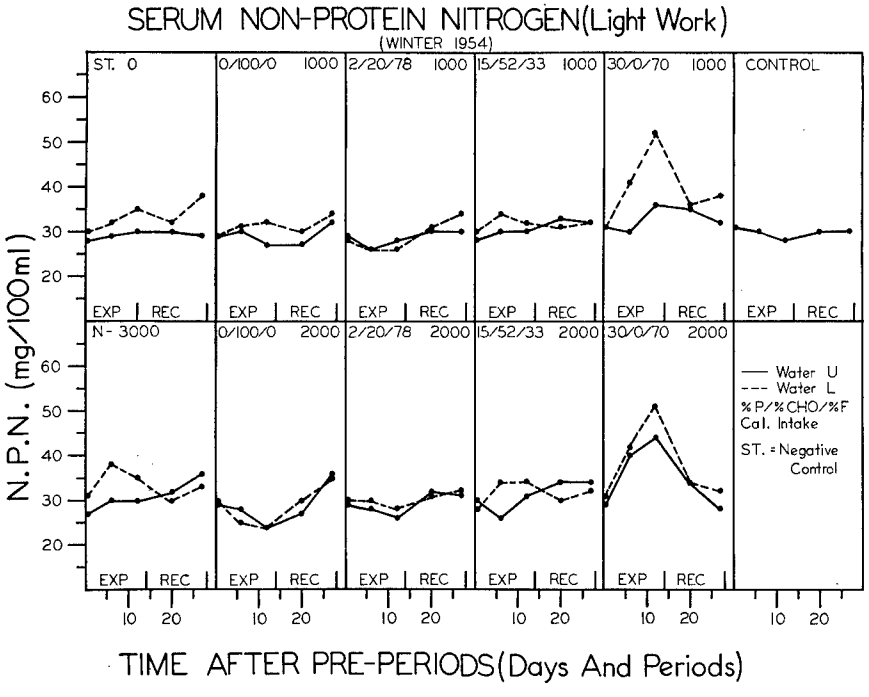


FIGURE III. 26

D. FUNCTIONS OF ENDOCRINE GLANDS

1. Pancreas

The only measure of the endocrine function of the pancreas was determination of blood sugar on blood collected during the two-hour test. The blood drawn for glucose analyses was not obtained from subjects in the "fasting" or postabsorptive state; i.e., they generally had not fasted for 16 hours prior to venipuncture. In most cases the blood was obtained four to six hours after the last meal. This fact is probably important in interpreting the results concerning glucose, for one would expect more variation in such samples than in the more usual "fasting" samples.

The mean values for blood sugar for P I and P II for the five groups of subjects are summarized in Table III. 51. There were some inter-group differences. Flight 3 averaged highest in both weeks of the pre-period. In general the two weeks were not appreciably different, but the control subjects had significantly higher values in the second week than in the first. The reason for this finding is not apparent. The mean values are generally lower than the accepted normal range: 76-96 mg/100 ml (Albritton, 1951) and than those measured in blood from eight "fasting" normal young men studied in 1953. The method used in 1954 was selected because it approximates "true" glucose; therefore the present values tend to be lower than those commonly reported in the literature.

Control Subjects. The mean blood glucose values for the leaders of flights performing hard work rose appreciably in EXP I and fell below the pre-period means in EXP II and then gradually returned toward pre-period values in the recovery period (Table III. 52 and Figure III. 27). On the other hand, the leaders for the flight doing light work fell during EXP I and EXP II and then rose again toward pre-period values in the recovery period (Figure III. 28). These trends are within three standard deviations and probably do not represent physiologically significant changes.

Experimental Subjects. The mean values for blood glucose were markedly altered by some of the experimental regimens.

Nutrient mixture: All dietary regimens except 15/52/33 3000 were correlated with some fall in the level of the blood glucose. In general, the fall was most marked in EXP I. In EXP II the mean values returned toward pre-period levels. The diminution was particularly great in the case of men subsisting on 30/0/70 and doing hard work and those on 2/20/78 and 30/0/70 and doing light work. Many of the values fell to hypoglycemic levels, and it is noteworthy that characteristic clinical symptoms of hypoglycemia did develop. (See section on Clinical Evaluation of Nutrient Combinations.)

Water intake: There was no consistent influence of water on the resting blood glucose.

Work load: The level of the blood glucose was not significantly different when the hard work group was compared with the light work group.

Recovery: During the two weeks of recovery the blood glucose tended to rise above the pre-period level. In a number of instances it reached values exceeding 80 mg/100 ml. This rebound was especially evident among men who had subsisted on ST 0 and 30/0/70. Some of the men who had been on 0/100/0 and 2/20/78 also rebounded.

TABLE III. 51

PRE-PERIOD DATA ON RESTING BLOOD SUGAR
(mg/100 ml)

Groups of Subjects	P I			P II		
	M	s.d.	C.V.	M	s.d.	C.V.
Flight 1	64	9.1	14.2	66	4.4	6.7
Flight 2	67	6.0	8.9	69	4.7	6.8
Flight 3	73	5.2	7.2	76	7.2	9.5
Flight 4	69	4.9	7.0	73	7.5	10.3
Controls	66*	6.3	9.6	75*	8.7	11.6

*Difference between two means significant at 1% level by "t" test.

TABLE III. 52

RESTING BLOOD SUGAR

Experimental Regimen		Hard Work					Light Work				
		Pre*	Exp		Rec		Pre*	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	63	56	64	58	66	76	48	53	70	86
	L	65	54	60	90	85	73	47	60	87	72
0/100/0	U	68	56	68	78	68	74	62	62	73	81
1000	L	64	62	69	74	69	75	62	66	84	70
0/100/0	U	69	50	72	59	78	77	63	72	74	72
2000	L	69	64	66	64	64	75	70	68	74	76
2/20/78	U	76	52	60	68	74	68	36	46	59	69
1000	L	67	64	56	78	76	69	28	40	75	72
2/20/78	U	64	58	62	64	66	77	48	60	86	73
2000	L	70	57	58	76	76	70	28	63	83	78
15/52/33	U	73	55	64	75	74	70	49	48	69	76
1000	L	68	52	55	76	70	71	59	69	76	71
15/52/33	U	63	54	62	71	70	69	58	65	75	67
2000	L	66	53	65	66	72	66	58	61	78	68
15/52/33	U	57	64	85	74	73	78	79	70	78	76
3000	L	66	58	66	85	75	79	60	65	77	75
30/0/70	U	64	28	56	59	73	77	46	52	79	88
1000	L	76	48	62	78	80	70	44	54	74	68
30/0/70	U	62	26	58	56	66	74	60	45	72	74
2000	L	67	49	64	70	76	62	40	59	68	62
Control	U	72	82	60	62	64	75	60	60	72	72
	L	71	85	63	68	75	66	61	59	61	63

*Mean values for PI and PII.

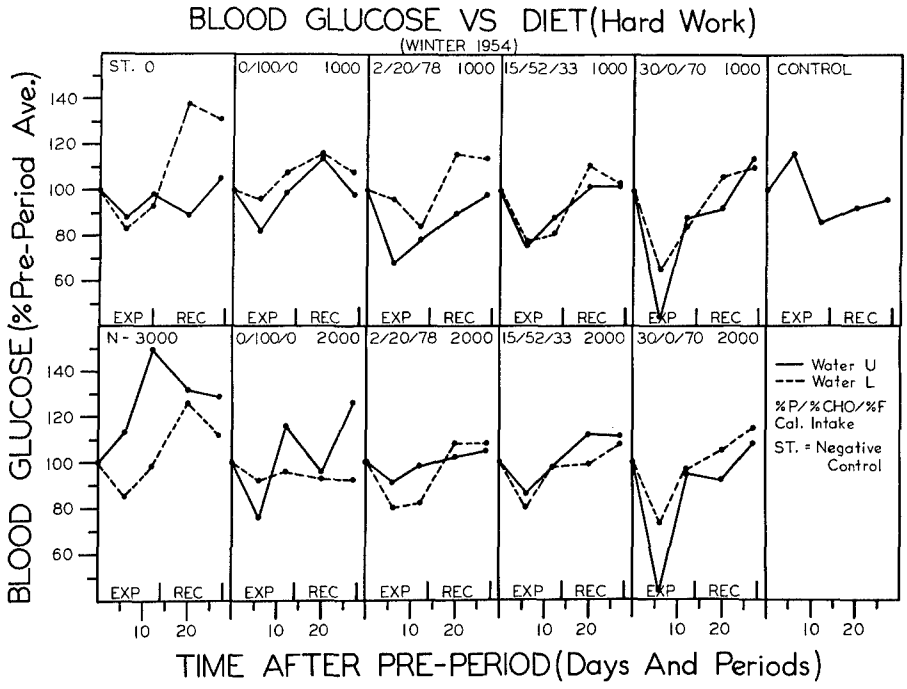


FIGURE III. 27. BLOOD GLUCOSE VS. DIET (HARD WORK), WINTER, 1954.

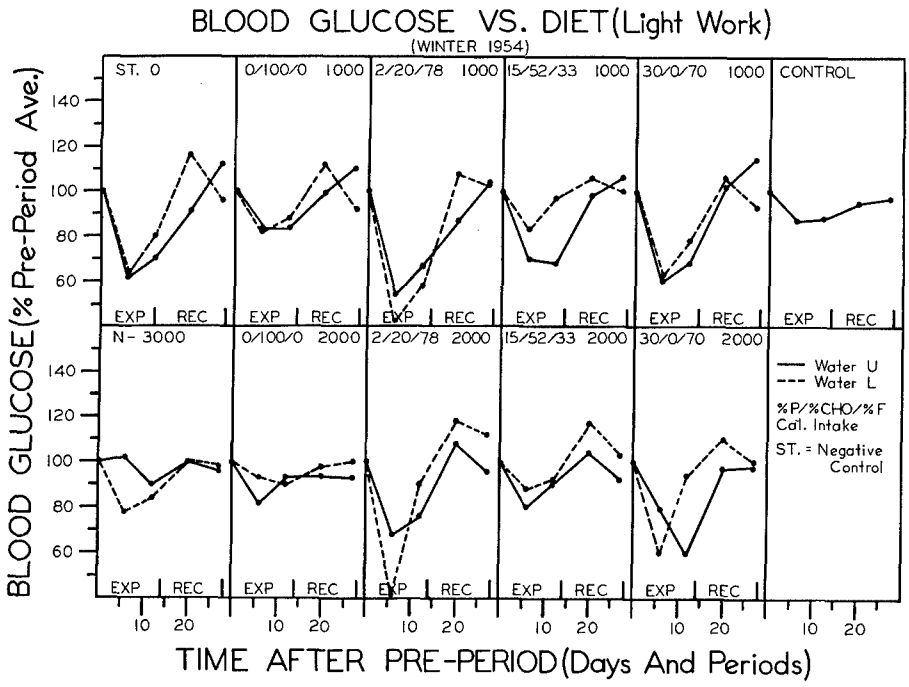


FIGURE III. 28. BLOOD GLUCOSE VS. DIET (LIGHT WORK), WINTER, 1954.

2. Adrenal Cortex

Urinary 17-Ketosteroids. Aliquots of the daily urines from each of the subjects, except the controls, were pooled for the first six days of each week. These weekly pools were subjected to analysis for 17-ketosteroid levels by means of the Vestergaard method of hydrolysis and extraction and the Zimmerman color reaction (Sargent et al., 1954).

The mean 17-ketosteroid values during P I and P II for the five groups of subjects are summarized in Table III. 53. Only one daily urine specimen was obtained during P II for each of the control subjects. There were some inter-group differences. Flight 3 had the highest mean value in both weeks of the pre-period. The control level was higher than that of any flight but did not differ significantly (at the 1% level) from that of Flight 3 during P II. The mean values for P II were slightly higher than those for P I. However no significant differences were found to exist between the means of the flights in either week nor were there significant differences between P I and P II. No individual value was as high in this winter test as was obtained in the temperate study of 1953 and some of the subjects were at the lower end of the normal range of 17-ketosteroids (6 - 8 mg/24 hrs). Flights 1 and 4 had most of these low values and this was reflected in the low mean values for each of them (Table III. 53).

Control subjects: The 17-ketosteroid values of the flight leaders who comprised the control groups fell only slightly during EXP II and rose toward normal at the end of recovery (Table III. 54; Figures III. 29 and III. 30). Unfortunately some of the urine samples were lost and some of the urines of the recovery period (April 3, 1954) were not treated with toluene and were contaminated with mold. The values obtained on the latter were discarded so there are not as many individuals represented as would be desired. There is no significant difference between the controls on hard work (Figure III. 29) and those on light work (Figure III. 30).

Experimental subjects: The mean values for 17-ketosteroids were markedly altered by some of the experimental regimens (Figures III. 29 and III. 30). The results conformed quite well to those of 1953. Starvation produced a marked, rapid fall of the 17-ketosteroid levels. At the 1000-Calorie level all the nutrient mixtures except 15/52/33 had the same sort of precipitous decrease in 17-ketosteroids. The drop was, on the whole, less pronounced at the 2000-Calorie level and again the least change occurred with the 15/52/33 nutrient mixture although 30/0/70 on hard work was similar. At both calorie levels the decrease during EXP I is greater than during EXP II and, in general, at the 2000-Calorie level there was a levelling off or a rise during EXP II (except for 0/100/0 and 2/20/78 on light work). At the 1000-Calorie level the decreased amounts of 17-ketosteroids continued from EXP I through EXP II except for 2/20/78 combined with light work. At the 3000-Calorie level the decrease from the pre-period levels was less than the effects produced by the other nutrient levels and in some cases the 17-ketosteroid levels were higher than normal. The results from this winter trial support the observations made last year that the 15/52/33 diet maintained the 17-ketosteroid levels closer to normal than did the other nutrient mixtures.

There was no consistent influence of water on the 17-ketosteroid levels and very few marked differences produced by limited water. On the diet, 30/0/70, which was expected to show up the greatest differences in this regard, the relative changes in 17-ketosteroids were almost identical. In only two dietary regimens, 0/100/0 and 2/20/78 on light work, were noticeable differences produced by water intake but the effects were reversed or insignificant for these two on hard work. At the 2000-Calorie level those on limited water in the hard work group on the 0/100/0 nutrient mixture had a far less decrease in 17-ketosteroids than those on unlimited water. However this difference did not occur in the 0/100/0 group on light work. One can only conclude that water intake manifested no apparent and consistent effect on the 17-ketosteroid levels in this winter trial.

The 17-ketosteroid levels did not vary appreciably between the groups on hard work and those on light work although at both the 1000- and 2000-Calorie levels the 15/52/33 groups doing light work showed less depression of the urinary 17-ketosteroid output than their counterparts on hard work.

Recovery: In almost all cases the 17-ketosteroid levels rose to or exceeded the mean pre-period levels in REC II. In no case did the level remain more than 8% below the pre-period level and in some cases the level went 20% above. No correlation with diet, water intake, or work are apparent in this rebound. No appreciable rise in 17-ketosteroids took place during REC I. In some cases, 15/52/33, the depression of the 17-ketosteroid level begun in EXP I and EXP II continued during REC I.

Adrenocortical Function: Serum Electrolytes. Some aspects of adrenocortical function may be investigated by study of the serum concentrations of sodium, potassium and chloride. In uncontrolled hypofunction of the adrenal cortex (e.g., Addison's disease), serum sodium and chloride tend to be abnormally low, and serum potassium to be high. In uncontrolled hyperfunction of the adrenal cortex (e.g., Cushing's syndrome) the serum potassium and chloride are abnormally low, the serum bicarbonate is high, and the sodium is usually high. The electrolyte changes are related to a hypokalemic, hypochloremic alkalosis. In the present study, samples of serum were obtained weekly from each subject as well as the controls.

Pre-Period data for serum sodium, potassium and chloride are given in Table III. 55. The values for all three electrolytes were in the normal range for all flights. A few mean values were statistically (but not physiologically) different in PRE I and PRE II. These were for sodium in Flights 2 and 4 and controls, potassium in Flights 2 and 3, and chloride in Flight 3. In each case, a very small standard deviation existed, and a very small difference was thus significant by the "t" test. All pre-period data were averaged for PRE I and PRE II for the purposes of this study.

During experimental and recovery weeks, sodium concentrations (Table III. 56) were remarkably constant, even in regimens very low in sodium, and no truly abnormal values were observed. A few minor, but consistent, changes are worth mentioning. In the hard work group, limitation of water was associated with a slightly higher serum sodium; in the light work group, the effect of

limitation of water was present only in regimens containing the most salt. Regardless of previous regimen or work load, REC I was almost always higher than EXP II and REC II. It will be recalled that there was a diuresis in REC II, associated with a decrease in hematocrit. The diminution of serum sodium between REC II and REC I probably was associated with hemodilution.

During the experimental and recovery periods serum potassium (Table III. 57) showed no changes worth mentioning. In fact, its constancy is amazing. There was no apparent effect of work load, water intake, caloric intake or calorie distribution.

In contrast to serum sodium and potassium, serum chloride (Table III. 58) did show consistent and significant changes, especially in EXP I and REC I, and especially in the hard work group. At the same time the controls were showing either no change, or changes different from those of the experimental subjects.

Without limitation of water, there was a decrease in serum chloride in EXP I in all hard work groups, and in seven of the ten light work groups. Limitation of water modified this decrease, so that only seven of the ten hard work groups showed it, and seven of the ten light work groups. Unusually low values (96 mEq/L or below) were observed in both hard and light work for ST 0, 0/100/0 1000, and 30/0/70 1000, and in the light work group for 0/100/0 2000, and 2/20/78 1000 as well. In all regimens, EXP II tended to be higher than EXP I. In the hard work group, this was true in twelve of the twenty comparisons, and in the light work group in fifteen of the twenty.

During REC I, values were higher than for PRE II. In the hard work group, this was true in sixteen of the twenty comparisons, and in the light work group, in fourteen. In REC II, there was a decrease. In the hard work group, this was true of eighteen of the twenty comparisons, and in the light work group, it was true in twelve of the twenty comparisons.

How can these changes in serum chloride be explained? No simple explanation suffices, and the problem is complicated further by the failure of sodium and chloride to follow parallel courses. The factors which must be considered are dietary intake, water intake, acid-base balance, and adaptive changes in endocrine and renal function. A final decision on these matters is not possible, although a strong case can be made for a primary influence of dietary intake, modified by dehydration when that occurred. The lowest values occurred in EXP I and EXP II on ST 0 and 1000-Calorie regimens of very low salt content. The highest values occurred in REC I, when salt intake was high. Dehydration tended to be associated with an increased serum chloride. Acid-base balance can probably be ruled out, even though there was known acidosis in some groups together with low chloride. In acidosis, chloride is replaced by the acid radicles, in this case, β-hydroxybutyric acid. The reason why acid-base balance cannot be considered the controlling factor is that low values were observed in the pure carbohydrate regimens, when there was no acidosis. Adaptive changes in endocrine and renal function are not attractive as explanations, for then one would expect sodium and potassium to show changes, which they did not. By elimination we are left with the dietary explanation for changes in chloride.

In EXP I and EXP II, so far as adrenocortical function is measured by serum sodium, potassium, and chloride, we must conclude that there were no striking persistent deviations from normal in any groups, either in the direction of hyperfunction or hypofunction. In REC I, there was a retention of sodium and chloride, followed in REC II by a diuresis, accompanied by expansion of the extracellular fluid. In REC II, therefore, one would expect to see a simultaneous decrease in hematocrit, and in serum chloride and sodium. This, in fact, was the case, and we do not interpret the findings in terms of adrenocortical function.

TABLE III. 53

PRE-PERIOD DATA ON URINARY 17-KETOSTEROIDS: WEEKLY POOLS
(mg/24 hrs)

Groups of Subjects	P I			P II		
	M	s.d.	C.V.	M	s.d.	C.V.
Flight 1	9.3	2.6	28.0	10.4	3.2	30.5
Flight 2	9.8	2.0	20.8	10.2	2.4	24.0
Flight 3	10.7	3.0	28.3	10.8	3.3	30.4
Flight 4	8.9	2.3	25.6	9.3	1.9	20.8
Controls*	----	---	----	13.7	4.6	34.0

*Value based on a single daily urine per man rather than a weekly pool.

TABLE III. 54

17-KETOSTEROID EXCRETION: WEEKLY POOLS
(mg/24 hrs)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	8.04	5.40	4.28	5.92	9.28	12.92	7.53	8.43	8.70	12.46
	L	9.45	7.98	7.08	5.80	9.65	8.50	5.87	5.13	5.57	9.27
0/100/0	U	8.48	6.60	5.75	6.45	9.50	12.12	8.00	6.45	6.50	11.30
1000	L	10.30	7.40	7.80	7.35	11.40	8.48	5.50	5.25	6.10	9.50
0/100/0	U	11.95	7.00	7.05	7.40	12.95	10.90	7.85	6.60	7.75	11.50
2000	L	9.60	8.25	8.10	8.45	9.60	10.50	9.20	7.35	6.45	10.75
2/20/78	U	10.58	6.50	5.25	7.65	12.40	7.88	5.35	6.10	7.50	9.15
1000	L	8.88	6.35	6.15	5.70	8.90	9.08	6.50	5.10	6.50	9.20
2/20/78	U	10.80	8.70	7.35	7.35	12.95	9.80	8.93	7.57	8.13	11.57
2000	L	11.98	7.90	7.60	10.10	13.65	11.30	10.30	7.30	7.25	10.75
15/52/33	U	13.70	11.60	9.90	8.80	15.50	7.05	6.25	6.10	5.35	8.50
1000	L	9.38	6.50	7.30	6.60	9.50	9.38	8.40	7.30	7.05	10.00
15/52/33	U	9.40	8.50	7.90	8.70	10.95	10.08	8.85	10.15	10.75	10.00
2000	L	11.88	8.45	9.30	9.45	13.70	8.02	7.80	8.15	7.40	8.90
15/52/33	U	8.35	6.85	8.95	7.80	9.25	15.10	13.95	13.60	13.90	18.53
3000	L	9.45	8.70	7.50	8.75	10.55	10.92	11.00	10.70	10.00	10.95
30/0/70	U	8.98	6.75	5.25	5.85	9.55	8.50	6.00	5.10	7.30	9.95
1000	L	10.38	7.60	6.00	7.15	12.35	7.90	6.85	5.25	5.25	7.85
30/0/70	U	9.55	7.45	7.80	7.85	10.50	11.22	8.15	7.30	8.05	11.45
2000	L	8.75	7.70	6.90	6.75	8.90	6.48	4.65	5.05	4.75	6.85
Control	U	13.70	-----	12.20	-----	12.80	13.70	-----	12.48	-----	13.35
	L	13.70	-----	12.20	-----	12.80	13.70	-----	12.48	-----	13.35

*Mean values for PI and PII.

FIGURE III. 29. URINARY 17-KETOSTEROID EXCRETION (HARD WORK), WINTER, 1954.

FIGURE III. 30. URINARY 17-KETOSTEROID EXCRETION (LIGHT WORK), WINTER, 1954.

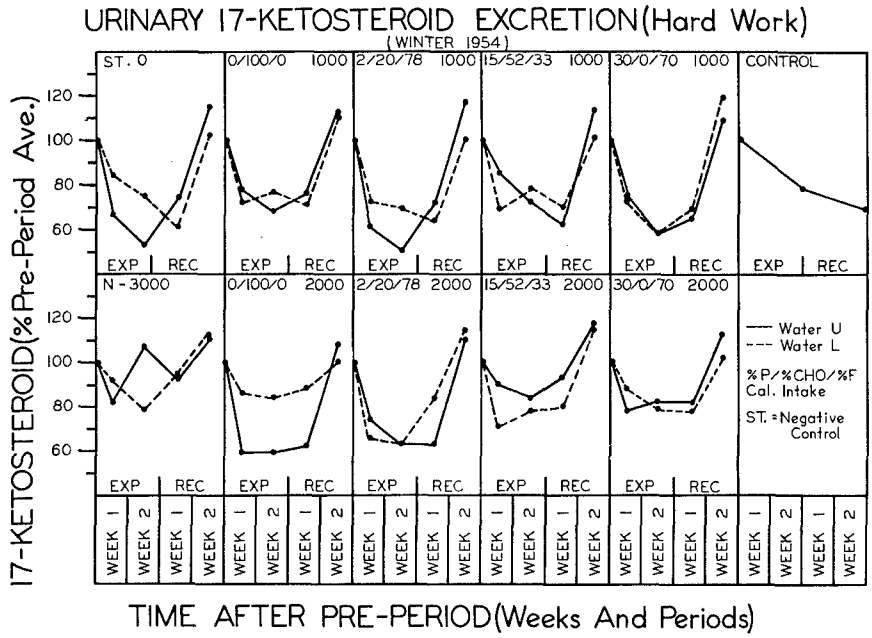


FIGURE III. 29

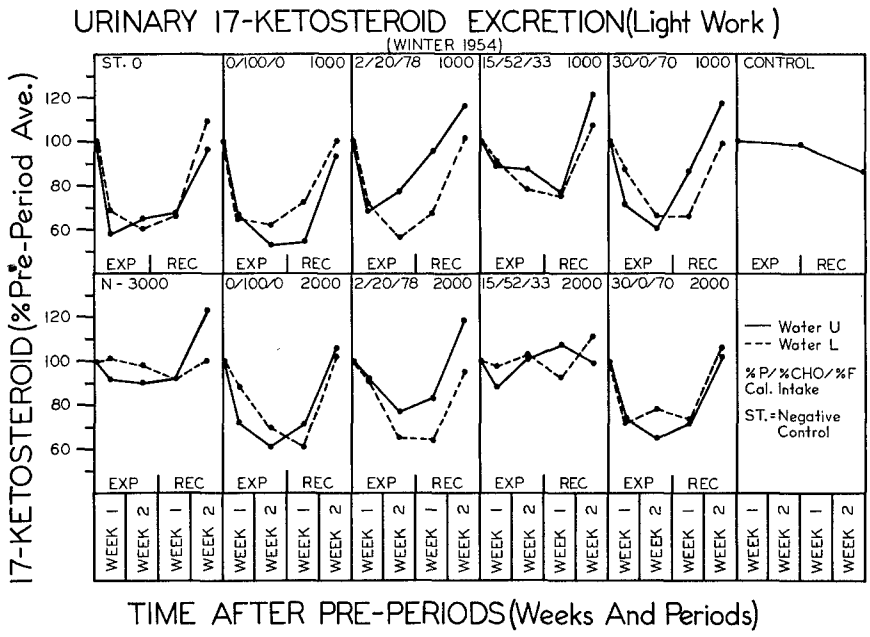


FIGURE III. 30

TABLE III. 55

PRE-PERIOD DATA ON SERUM ELECTROLYTES:
SODIUM, POTASSIUM AND CHLORIDE

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
			Na, mEq/l			
Flight 1	138	2	1.4	139	4	2.9
Flight 2**	135	2	1.5	138	2	1.4
Flight 3	136	2	1.5	137	2	1.5
Flight 4**	137	2	1.5	139	2	1.4
Controls**	136	2	1.5	138	2	1.4
			K, mEq/l			
Flight 1	4.1	0.4	9.8	4.0	0.3	7.5
Flight 2**	4.5	0.3	6.7	4.1	0.3	7.3
Flight 3**	3.9	0.3	7.7	4.3	0.2	4.7
Flight 4	4.1	0.4	9.8	4.2	0.1	2.4
Controls	4.2	0.5	11.9	4.1	0.2	4.9
			Cl, mEq/l			
Flight 1	102	2	2.0	103	2	1.9
Flight 2	102	3	2.9	102	2	2.0
Flight 3**	103	1	1.0	101	2	2.0
Flight 4	102	2	2.0	101	2	2.0
Controls	102	2	2.0	102	2	2.0

**Means significantly different at 1% level by "t" test.

TABLE III. 56

SERUM SODIUM
(mEq/L)

Experimental Regimen		Hard Work					Light Work				
		Pre*	Exp		Rec		Pre*	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	137	139	136	145	140	137	137	139	140	140
	L	136	137	137	142	139	138	137	136	142	140
0/100/0	U	138	139	138	142	140	137	139	140	142	140
1000	L	137	137	139	141	140	139	140	138	142	140
0/100/0	U	136	142	137	145	140	135	141	140	143	141
2000	L	137	138	138	139	140	137	138	139	140	140
2/20/78	U	140	140	136	145	142	136	138	140	140	138
1000	L	137	144	140	142	140	139	138	139	139	138
2/20/78	U	142	140	140	143	141	139	141	141	142	139
2000	L	137	144	144	143	142	137	140	142	141	140
15/52/33	U	138	140	140	142	140	135	139	139	144	140
1000	L	136	143	142	142	142	139	140	140	143	138
15/52/33	U	136	138	140	142	138	136	139	138	142	139
2000	L	136	142	142	142	140	137	138	143	142	139
15/52/33	U	140	140	140	140	140	137	139	138	142	140
3000	L	136	139	144	138	140	140	142	147	139	140
30/0/70	U	140	138	135	145	140	137	138	140	142	141
1000	L	137	140	140	142	140	140	138	139	140	138
30/0/70	U	140	138	140	146	140	136	136	138	142	140
2000	L	138	139	144	146	140	138	140	142	142	138
Control	U	137	141	141	141	140	136	140	140	142	139
	L	137	142	142	143	140	138	139	141	140	140

*Mean values for PI and PII.

TABLE III. 57

SERUM POTASSIUM
(mEq/L)

Experimental Regimen		Hard Work					Light Work				
		Pre*	Exp		Rec		Pre*	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	4.1	5.0	4.7	4.2	4.0	4.1	4.5	4.2	4.0	4.0
	L	4.2	4.8	4.6	4.2	4.2	4.4	4.7	4.6	4.2	4.1
0/100/0	U	4.1	4.6	4.4	4.4	4.2	4.1	4.0	4.0	4.1	4.2
1000	L	4.6	4.8	4.4	4.7	4.4	4.2	4.2	3.9	4.0	4.0
0/100/0	U	4.1	4.1	4.6	4.6	4.0	3.9	3.7	3.9	4.1	4.1
2000	L	4.3	4.3	3.9	4.6	4.2	4.2	4.1	4.0	4.2	4.2
2/20/78	U	4.0	4.6	4.6	4.6	4.3	4.2	4.0	4.1	4.0	4.0
1000	L	4.4	4.6	4.4	4.6	4.3	4.0	4.3	4.2	4.2	4.0
2/20/78	U	4.0	4.2	4.2	4.2	4.0	4.1	4.1	4.0	4.2	4.1
2000	L	4.5	4.4	4.4	4.9	4.6	4.1	4.4	4.3	4.2	4.2
15/52/33	U	4.0	4.4	4.5	4.3	4.0	4.3	4.0	4.4	4.0	4.2
1000	L	4.4	4.6	4.4	4.4	4.5	4.0	3.9	4.1	4.0	4.0
15/52/33	U	4.3	4.3	4.6	4.8	4.2	4.3	4.0	3.8	4.2	4.2
2000	L	4.1	4.4	4.2	4.4	4.4	4.2	4.0	4.0	4.0	4.2
15/52/33	U	3.8	4.4	4.1	4.4	4.0	4.3	3.8	4.0	4.2	4.2
3000	L	4.6	4.6	4.5	4.6	4.4	4.1	3.8	4.1	4.0	4.0
30/0/70	U	4.0	4.4	4.4	4.4	4.2	3.8	3.6	4.2	4.1	4.0
1000	L	4.2	4.4	4.6	4.5	4.4	4.4	4.2	4.3	4.5	4.2
30/0/70	U	3.9	4.2	4.6	4.1	4.0	4.1	3.9	4.1	4.2	4.2
2000	L	3.8	4.4	4.5	4.2	4.2	4.1	4.0	4.2	4.4	4.3
Control	U	4.0	4.1	4.1	4.1	4.0	4.6	4.0	4.1	4.2	4.1
	L	4.0	4.1	4.0	4.1	3.9	4.0	4.1	4.2	4.1	4.1

*Mean values for PI and PII.

TABLE III. 58

SERUM CHLORIDE
(mEq/L)

Experimental Regimen		Hard Work Pre*	Exp I	Exp II	Rec I	Rec II	Light Work Pre*	Exp I	Exp II	Rec I	Rec II
ST 0	U	103	98	94	108	100	103	96	96	104	101
	L	102	95	99	108	100	100	93	95	102	102
0/100/0	U	103	96	96	106	100	102	96	100	106	102
1000	L	102	95	99	108	98	102	96	97	104	100
0/100/0	U	101	99	98	106	102	102	96	101	101	102
2000	L	104	100	99	106	103	102	100	100	104	103
2/20/78	U	105	98	99	108	103	103	95	102	103	102
1000	L	102	102	101	104	102	102	98	101	103	100
2/20/78	U	102	100	102	104	100	103	100	102	102	101
2000	L	102	100	103	102	102	101	100	100	102	100
15/52/33	U	102	98	98	108	100	104	101	102	106	100
1000	L	103	100	104	106	100	102	100	100	104	102
15/52/33	U	104	98	101	105	102	101	102	101	102	102
2000	L	104	105	108	100	102	102	102	109	104	104
15/52/33	U	105	99	102	104	102	102	103	105	104	103
3000	L	103	102	106	104	102	102	104	108	100	103
30/0/70	U	100	92	90	106	102	101	94	95	102	101
1000	L	100	100	101	107	102	102	98	102	100	105
30/0/70	U	100	98	98	106	100	103	101	104	104	104
2000	L	104	100	105	102	100	101	101	110	99	100
Control	U	102	100	101	102	101	103	104	105	100	103
	L	102	103	102	102	102	101	100	99	98	102

*Mean values for PI and PII.

3. Parathyroid Gland

Diagnosis of changes in function of the parathyroid gland can be made from measurements of the serum calcium, serum inorganic phosphate, and serum alkaline phosphatase. In primary hyperparathyroidism, the concentrations of calcium and phosphatase tend to increase, and the concentration of phosphate to decrease. In hypoparathyroidism, the concentration of calcium tends to decrease, the phosphatase remains normal, and the phosphate increases.

Pre-Period data for serum calcium, inorganic phosphate, and alkaline phosphatase are shown in Table III. 59. The values for all flights for calcium were in the upper normal range and not different in the two weeks. The same was true for serum inorganic phosphate. In contrast, phosphatase increased in P II significantly in all flights, as well as in the controls, and in Flights 3 and 4 were definitely abnormally high by the usual clinical standard of 4.0 units as the upper limit of normal for adults. However, the youth of our subjects may have affected their values, for 10.0 is considered the upper limit of normal for children. During experimental periods and in recovery, serum calcium (Table III. 60) showed no consistent or diagnostic

pattern in the small changes that did occur. One high value of 19.0 was obtained in EXP I, 2/20/78 1000, but this dropped back to 11.0 in EXP II. No specific effects of work, water intake, calories, or calorie ratio are apparent.

Serum inorganic phosphate (Table III. 61) did show certain changes, which we interpret as being non-specific because they were shown by the ration controls as well as all experimental groups. As compared with the mean of PRE I and PRE II, EXP II was high in 17 of 22 cases 3 in both hard and light work groups. Again, REC II was higher than REC I in all but three of the 44 comparisons. Many very high values (i.e., above 5.5 mg/100 ml) were obtained in REC II. However, no specific effect could be detected in EXP I or EXP II of work, water, calorie intake, or calorie ratio.

Alkaline phosphatase in the serum (Table III. 62) varied from week to week in a non-specific way, the controls showing changes similar to the experimental groups. PRE II was higher than PRE I; EXP II was lower than EXP I. REC II was very low in the hard work groups, but not in the light work groups. (One subject accounted for the very high values of 30/0/70 L 2000 light work.)

We adopt the conservative interpretation that there is no convincing evidence of a change in parathyroid function in any groups as a result of the nutritional stresses imposed on the subjects of the present investigation.

TABLE III. 59
PRE-PERIOD DATA ON SERUM CALCIUM,
INORGANIC PHOSPHATE, AND ALKALINE PHOSPHATASE

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
			Serum Calcium, mg/100 ml			
Flight 1	10.5	1.0	9.5	10.8	1.1	10.2
Flight 2	11.0	0.8	7.3	11.1	1.0	9.0
Flight 3	10.4	1.1	10.6	10.9	0.7	6.4
Flight 4	10.7	0.7	6.5	10.8	0.7	6.5
Controls	10.5	0.8	7.6	10.6	1.1	10.4
			Serum Inorganic Phosphate, mg/100 ml			
Flight 1	4.6	0.6	13.0	5.0	0.4	8.0
Flight 2	4.8	0.7	14.6	5.0	0.7	14.0
Flight 3	3.8	0.5	13.2	3.8	0.5	13.2
Flight 4	4.0	0.5	12.5	4.5	0.4	8.9
Controls	3.5	0.5	14.3	4.1	0.5	12.2
			Serum Alkaline Phosphatase, Bodansky Units/100 ml			
Flight 1*	2.8	0.9	32.1	4.2	1.1	26.2
Flight 2*	3.3	1.3	39.4	5.4	1.8	33.4
Flight 3*	4.0	1.0	25.0	7.9	1.8	22.8
Flight 4*	4.4	2.1	47.7	8.3	3.3	39.8
Controls*	2.0	0.7	35.0	3.9	1.2	30.8

*Differences between mean significant at 1% level.

TABLE III. 60

SERUM CALCIUM
(mg/100 ml)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	11.1	10.2	10.2	9.7	10.3	9.8	10.6	10.0	10.7	9.9
	L	10.6	10.7	9.8	9.8	10.3	10.9	11.2	11.0	9.5	10.0
0/100/0	U	11.1	9.6	10.4	10.2	11.0	10.4	10.2	10.8	9.7	10.1
1000	L	11.3	9.1	9.8	11.0	10.8	10.6	10.7	11.2	11.6	10.2
0/100/0	U	9.2	10.6	10.2	9.5	11.2	11.0	10.3	10.4	10.5	10.1
2000	L	11.0	10.2	10.0	10.7	9.8	10.0	10.4	10.0	9.8	9.5
2/20/78	U	10.5	9.8	10.4	10.7	10.1	11.2	9.8	10.4	10.3	10.8
1000	L	10.9	12.0	11.0	9.9	9.7	10.6	10.4	10.5	10.0	10.0
2/20/78	U	11.2	10.2	10.0	11.0	9.4	11.6	9.8	11.4	11.0	10.8
2000	L	11.6	11.4	10.2	11.0	10.6	10.9	10.0	11.0	11.0	9.6
15/52/33	U	9.8	9.7	9.6	9.4	10.7	10.6	9.6	9.4	11.3	9.9
1000	L	10.9	10.6	10.4	10.6	11.4	10.2	10.8	10.8	10.4	9.8
15/52/33	U	10.7	10.2	10.4	10.6	10.4	10.8	9.6	11.1	10.5	10.3
2000	L	10.8	11.2	11.2	11.0	10.0	10.8	10.2	11.0	11.2	9.5
15/52/33	U	10.6	10.0	9.5	11.6	10.4	11.1	10.6	10.8	11.0	10.2
3000	L	10.8	11.3	10.4	11.2	9.8	11.2	9.8	10.4	10.3	10.6
30/0/70	U	10.8	9.8	9.6	9.8	10.0	10.1	10.6	10.0	10.5	10.3
1000	L	10.7	11.8	11.6	11.2	10.2	11.0	10.7	11.1	11.5	9.9
30/0/70	U	10.7	10.8	10.2	10.7	10.6	10.2	9.4	10.3	9.9	10.4
2000	L	12.1	9.9	9.5	10.7	10.8	11.3	10.0	10.5	10.7	9.3
Control	U	10.0	10.1	11.2	10.6	11.7	11.6	9.4	10.4	10.7	9.8
	L	10.1	10.6	10.2	9.9	9.9	10.4	10.1	10.9	10.7	10.0

*Mean values for PI and PII.

TABLE III. 61

SERUM INORGANIC PHOSPHATE
(mg/100 ml)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	4.7	4.2	5.4	5.5	6.1	3.9	4.3	4.2	4.4	4.8
	L	5.5	4.3	5.6	3.4	5.8	4.2	3.8	4.3	5.2	5.3
0/100/0	U	5.2	4.6	5.0	5.2	6.2	3.8	4.2	4.2	4.0	5.5
1000	L	4.4	4.3	4.9	3.9	5.4	4.5	4.4	4.5	4.2	5.9
0/100/0	U	4.2	3.4	5.0	4.6	5.4	4.2	4.4	4.8	5.4	5.8
2000	L	4.6	4.2	5.0	3.9	5.4	4.2	3.7	4.0	4.8	5.5
2/20/78	U	5.1	4.0	6.0	6.1	5.9	3.9	4.8	4.4	4.5	5.8
1000	L	4.9	4.0	4.8	4.0	5.9	4.2	3.8	4.0	4.2	5.1
2/20/78	U	5.1	4.8	5.1	5.2	5.8	4.1	4.3	4.3	4.2	5.5
2000	L	5.1	4.6	4.8	4.6	5.8	4.0	4.4	4.3	4.6	5.0
15/52/33	U	4.6	4.2	5.0	4.5	5.7	4.0	4.4	4.8	3.6	5.6
1000	L	4.8	4.4	5.1	4.0	5.8	4.1	3.9	4.2	4.6	4.8
15/52/33	U	4.6	4.2	5.4	5.6	6.0	3.3	4.8	4.7	4.8	5.6
2000	L	4.1	3.2	4.8	3.0	5.0	4.2	4.0	3.9	4.6	4.9
15/52/33	U	4.9	3.6	5.4	5.0	5.6	3.4	4.1	4.8	5.0	5.9
3000	L	5.0	4.2	5.3	4.4	6.0	3.6	4.2	4.0	4.8	4.8
30/0/70	U	4.9	4.1	5.0	5.5	6.0	4.0	4.0	4.3	4.4	5.8
1000	L	4.9	3.8	4.7	3.9	6.1	4.9	5.0	4.8	5.1	5.6
30/0/70	U	4.6	4.2	5.6	5.2	5.9	3.2	3.4	4.5	4.2	5.6
2000	L	4.7	4.2	5.3	4.4	5.9	4.7	5.1	4.8	4.8	5.6
Control	U	3.8	3.8	4.6	4.6	4.9	3.4	3.8	4.5	4.5	4.9
	L	4.0	3.4	4.8	4.2	4.7	3.9	4.1	4.4	4.8	4.4

*Mean values for PI and PII.

TABLE III. 62

PARATHYROID FUNCTION: SERUM ALKALINE PHOSPHATASE
(Bodansky Phosphatase Units/100 ml)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	3.0	3.7	3.7	2.1	2.0	1.3	4.1	7.8	4.7	2.8	3.8	2.9
	L	4.3	5.6	5.2	3.2	3.6	1.2	3.9	8.1	6.1	2.8	3.2	4.1
0/100/0	U	3.0	5.4	4.4	3.6	3.0	1.8	4.4	8.7	5.1	2.8	4.0	2.8
1000	L	3.7	3.5	4.8	2.5	4.5	2.2	4.5	9.8	6.9	4.4	4.4	4.2
0/100/0	U	2.2	3.8	4.9	2.8	1.2	1.2	5.3	9.2	7.4	4.0	4.6	3.8
2000	L	2.0	5.2	3.9	2.9	3.3	1.0	4.4	5.8	10.4	4.0	3.2	3.5
2/20/78	U	4.6	5.5	5.8	3.8	1.8	1.5	3.8	7.8	5.3	2.8	4.7	3.6
1000	L	2.4	4.5	3.9	2.0	4.0	1.4	3.0	5.7	4.8	2.2	2.7	3.4
2/20/78	U	2.7	4.2	3.6	2.0	1.5	0.8	4.3	7.2	5.2	2.8	4.0	3.3
2000	L	3.7	4.6	4.6	3.0	5.4	1.4	4.4	6.2	6.6	3.7	4.1	4.4
15/52/33	U	2.7	4.4	3.8	2.6	7.2	1.6	3.8	10.0	7.0	2.6	5.2	3.3
1000	L	3.0	5.8	5.0	2.4	3.2	1.2	3.1	12.7	5.7	3.1	4.3	4.6
15/52/33	U	2.1	3.9	3.6	2.4	2.2	1.5	2.4	7.5	5.1	2.8	4.0	3.2
2000	L	3.8	5.4	3.8	2.0	3.8	1.1	3.2	8.2	6.6	3.9	4.5	4.8
15/52/33	U	2.2	3.5	3.3	2.0	1.8	1.2	3.4	7.2	6.4	3.1	4.7	3.2
3000	L	4.9	8.4	6.4	3.3	5.1	1.3	3.2	5.6	5.9	2.6	4.4	4.1
30/0/70	U	1.6	3.9	4.0	2.2	2.0	1.6	4.2	8.2	5.2	3.1	3.8	3.2
1000	L	2.0	4.2	3.1	1.9	4.9	1.0	6.0	6.8	8.8	4.6	5.4	6.3
30/0/70	U	2.8	5.0	5.8	3.9	2.5	1.4	3.7	6.0	4.8	2.8	4.2	2.2
2000	L	2.2	6.2	4.4	3.0	5.5	1.4	8.8	9.2	17.2	7.6	8.2	11.2
Control	U	1.7	2.9	3.2	1.8	1.8	0.9	1.4	5.2	4.4	2.4	3.1	2.5
	L	2.8	4.7	4.7	2.1	3.5	0.9	2.2	2.7	4.2	2.1	4.3	3.8

4. Thyroid Function

In this cold weather test, it was planned to obtain information on changes in thyroid function from two sets of data; these were, first, oxygen consumption in the resting subject, and second urinary excretion of creatine during the two hour test. Because of very large coefficients of variation in both sets of data, certain interpretation of small changes is difficult if not impossible. Only gross changes are meaningful.

As may be seen from the data in the section on respiratory metabolism, the oxygen consumption (i.e., heat production) diminished during EXP I and EXP II in all groups of subjects on low calorie regimens, the ration controls remaining relatively constant. The high protein diet 30/0/70 2000 showed the least diminution, presumably because of the high specific dynamic action of protein. In REC I, heat production was increased. Beyond this, it is statistically injudicious to relate changes to specific regimens. The 1954 data in a general way agree with those of 1953. However, the latter were far more precise and interpretable, and we prefer to base detailed conclusions on heat production on the 1953 data.

The rate of excretion of creatine in the urine is correlated with the kind and severity of thyroid disease. In hyperthyroidism, creatinuria may be marked; in hypothroidism, there is an abnormally low excretion of creatine. Further, age and sex have a marked influence. In women, creatinuria is consistently present, and also in children of both sexes. In adult men, there is a small, sometimes absent, excretion of creatine. All of our subjects in 1954 did excrete creatine in measurable amounts in one or more of the six weeks (Tables III. 63 and 64). This finding agrees with the same observation made on this point in 1953, and supports the contention of many who claim creatine to be a normal constituent of the urine of healthy young men (e.g., Albanese and Wangerin, 1944). It should be remembered that our subjects were very young adults, and one might argue that in respect of creatinuria they were reacting more like children than adults.

Although the coefficients of variation were high, certain conclusions may be drawn, especially in the hard work groups. Table III. 63 for the pre-period shows a range of excretion from 0.1 to 0.4 mg/min. In the hard work groups (Table III. 64) those on unlimited water tended to go beyond this range in EXP I or EXP II especially in the 30/0/70 regimens and in 15/52/33 3000, and in all groups during REC I or REC II, or both, those previously on unlimited water had large excretions. These changes were minimal or absent in the restricted water groups. Turning to the light work groups (Table III. 64) we find few if any of the changes noted for the hard work group. During EXP I and EXP II, unlimited water was not correlated with marked creatinuria. During REC I and REC II there was little if any tendency for increased excretion in the light work groups, and there were no apparent differences between those previously on limited water, and those on unlimited water.

Can we interpret all the changes in oxygen consumption and in creatine excretion as directly related to changes in thyroid function, and say that there was a marked increase in REC I and REC II, especially in the hard work groups previously on unlimited water? The definite answer cannot be given, and we are inclined toward conservatism in our interpretation. A diminished heat production is the invariable accompaniment of caloric deficiency, and is not necessarily related to thyroid function; it can also be related to a diminished supply of subtrates upon which the oxidative mechanisms of the body work. Repletion is accompanied by increased heat production with increased subtrates. Also, in caloric deficiency, there is tissue breakdown, more marked the greater the negative caloric balance. In other words, there is an increased amino acid turnover, with a chance for increased excretion of creatine. Now, all reactions in the body go on in a fluid matrix, and we should like to speculate that chronic dehydration will not permit the same rate of amino acid turnover as a normal state of hydration. We know that the hard work groups underwent a more severe caloric deficiency than the light work groups. If then those with unlimited water underwent the greatest degree of tissue breakdown, we should expect a continuing greater protein turnover also in repletion: In brief, we are thinking in terms of enzyme-substrate relationships in a fluid matrix, rather than in terms of specific thyroid activity.

TABLE III. 63

PRE-PERIOD DATA ON MINUTE URINARY EXCRETION OF CREATINE
(mg/min)

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
Flight 1	0.14	0.15	108.0	0.14	0.10	71.4
Flight 2	0.15	0.29	193.3	0.18	0.17	94.5
Flight 3	0.35	0.21	60.0	0.18	0.20	90.0
Flight 4**	0.21	0.16	76.2	0.42	0.25	59.4
Controls	0.17	0.16	94.3	0.22	0.18	81.8

**Differences of means significant at 1% level by "t" test.

TABLE III. 64

MINUTE URINARY EXCRETION OF CREATINE
(mg/min)

Experimental Regimen		Hard Work Pre*	Exp I	Exp II	Rec I	Rec II	Light Work Pre*	Exp I	Exp II	Rec I	Rec II
ST 0	U	0.12	0.31	0.07	0.72	0.89	0.08	0.35	0.34	0.37	0.25
	L	0.15	0.42	0.24	0.32	0.54	0.24	0.26	0.08	0.34	0.22
0/100/0	U	0.16	0.52	0.38	0.64	0.82	0.35	0.26	0.22	0.00	0.15
1000	L	0.40	0.26	0.16	0.40	0.07	0.45	0.15	0.04	0.08	0.24
0/100/0	U	0.23	0.31	0.42	0.68	0.75	0.29	0.58	0.21	0.19	0.08
2000	L	0.15	0.10	0.16	0.06	0.09	0.34	0.14	0.04	0.28	0.32
2/20/78	U	0.08	0.12	0.34	0.42	0.52	0.24	0.00	0.16	0.22	0.12
1000	L	0.16	0.14	0.12	0.13	0.08	0.24	0.33	0.15	0.00	0.06
2/20/78	U	0.07	0.16	0.44	0.73	0.58	0.26	0.22	0.44	0.36	0.41
2000	L	0.02	0.20	0.11	0.34	0.12	0.23	0.22	0.07	0.00	0.08
15/52/33	U	0.21	0.18	0.30	0.48	0.54	0.28	0.26	0.32	0.26	0.46
1000	L	0.00	0.24	0.32	0.43	0.02	0.23	0.18	0.36	0.04	0.08
15/52/33	U	0.15	0.56	0.60	0.50	0.64	0.37	0.13	0.14	0.08	0.11
2000	L	0.24	0.33	0.18	0.38	0.26	0.28	0.35	0.10	0.10	0.18
15/52/33	U	0.00	0.45	0.87	0.62	0.56	0.38	0.30	0.24	0.16	0.08
3000	L	0.23	0.62	0.30	0.54	0.22	0.55	0.51	0.12	0.46	0.11
30/0/70	U	0.21	0.50	1.00	0.70	0.90	0.29	0.36	0.12	0.27	0.16
1000	L	0.20	0.19	0.50	0.20	0.08	0.41	0.30	0.16	0.13	0.20
30/0/70	U	0.16	0.92	0.36	0.18	0.64	0.24	0.54	0.38	0.20	0.14
2000	L	0.25	0.52	0.54	0.32	0.00	0.23	0.61	0.45	0.10	0.20
Control	U	0.12	0.41	0.47	0.06	0.28	0.21	0.43	0.00	0.60	0.06
	L	0.16	0.48	0.35	0.66	0.04	0.29	0.36	0.12	0.08	0.10

*Mean values for PI and PII.

E. OTHER ORGAN AND SYSTEM FUNCTIONS

1. Liver Function

Serum Cholinesterase. Table III. 65 contains the pre-period data for serum cholinesterase by groups of subjects. The means and standard deviations agree closely with the results from the 1953 study. Two flights, 1 and 2, showed significant decreases from P I to P II. One subject (No. 87) had a serum cholinesterase which averaged about 0.20 ΔpH/hr. This level is definitely abnormal, but the subject gave no history of liver disease and had normal serum alkaline phosphatase and total cholesterol. The cause of the marked depression was not apparent from the available clinical and laboratory observations on him.

Marked variations in serum cholinesterase were correlated with subsistence on the several experimental regimens (Table III. 66) and the trends are strikingly similar to those observed in the 1953 study. For the hard work groups several significant trends stand out (Figure III. 31). (1) The controls and the subjects on 15/52/33 2000 and 3000 and 2/20/78 2000 exhibited relatively little change. (2) Men on ST 0 showed the greatest depression. (3) With the exception of 0/100/0, greater reductions were evident for the 1000-Calorie regimens than for the 2000-Calorie. The changes on the pure carbohydrate ration were striking similar regardless of calorie intake. (4) Water intake did not consistently and significantly modify the serum cholinesterase. (5) Full recovery of the serum cholinesterase to pre-period levels did not occur after some two weeks of rehabilitation.

Men performing light work showed some striking quantitative differences from those doing hard work. (Figure III. 32). The significant observations are: (1) The controls and the subjects on 15/52/33 3000 exhibited relatively little change. (2) Men on ST 0 showed the greatest depression. (3) Men on limited water reacted in much the same manner as did the men in the hard work groups. (4) Men on unlimited water either exhibited a small reduction or a rise in serum cholinesterase during EXP I and EXP II. (5) In the case of most of the regimens, the serum cholinesterase had not returned to pre-period values after two weeks of recovery.

One major difference between the 1953 and the 1954 results is that the serum cholinesterase levels did not return to control levels after two weeks of rehabilitation. A reason for this fact may lay in the manner in which rehabilitation was handled in the two years. In 1953 food intake was not restricted in REC I. In 1954, the subjects were not allowed to eat freely until the fourth day of rehabilitation. This restriction may have retarded the full recovery of this aspect of liver function.

Serum Total Cholesterol. In the 1954 tests a different method was employed for determining serum cholesterol than had been used in 1953. In preliminary trials the anthrone procedure (c.f. Section II: Methods) proved very satisfactory. When applied to large scale work such as was demanded in the present investigation, the procedure proved to be most tedious and time-consuming. Results were far from satisfactory and many repeat analyses had to

be made before reasonable values were obtained. We do not recommend the method for routine work, especially when large numbers of samples must be analyzed.

In spite of all our difficulties, the pre-period data agree remarkably well with results reported in 1953 (Table III. 67). The means and their variability are similar to those for the eight volunteer students. Flight 4 had a low mean in P I; this value we can not explain. The results indicate that, in general, there were no significant changes from P I to P II.

The paired means for the several phases of the study are given in Table III. 68. Examination fails to reveal any trends correlated with work, water, or nutrient mixture. The marked increase in cholesterol associated with regimens containing meat bar was not found in this investigation.

TABLE III. 65

PRE-PERIOD DATA ON SERUM CHOLINESTERASE
(ΔpH/hr)

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
Flight 1*	1.01	0.18	17.8	0.88	0.15	17.1
Flight 2**	0.96	0.14	14.6	0.82	0.12	14.6
Flight 3	0.78	0.21	26.9	0.81	0.19	23.5
Flight 4	0.83	0.19	22.9	0.78	0.20	25.6
Controls	0.84	0.19	22.6	0.85	0.17	20.0

*Difference of means significant at 2% level by "t" test.
**Difference of means significant at 1% level by "t" test.

TABLE III. 66

SERUM CHOLINESTERASE
(ΔpH/hr)

Experimental Regimen		Hard Work					Light Work				
		Pre*	Exp		Rec		Pre*	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	0.87	0.71	0.62	0.38	0.64	0.89	0.96	0.80	0.58	0.71
	L	0.85	0.76	0.64	0.48	0.55	0.88	0.95	0.64	0.52	0.62
0/100/0	U	1.08	1.00	0.74	0.56	0.72	0.69	0.64	0.56	0.50	0.58
1000	L	0.83	0.67	0.69	0.49	0.65	0.79	0.88	0.68	0.60	0.58
0/100/0	U	0.93	0.79	0.74	0.52	0.70	0.60	0.58	0.57	0.51	0.56
2000	L	0.85	0.66	0.63	0.50	0.61	0.81	0.82	0.66	0.54	0.61
2/20/78	U	1.00	0.96	0.80	0.56	0.70	0.88	0.98	0.95	0.73	0.78
1000	L	0.94	0.84	0.77	0.62	0.67	0.81	0.80	0.62	0.60	0.67
2/20/78	U	0.98	0.90	0.72	0.78	0.76	0.75	0.90	0.91	0.80	0.77
2000	L	0.75	0.65	0.70	0.61	0.61	0.71	0.70	0.58	0.52	0.56
15/52/33	U	0.95	0.97	0.76	0.52	0.70	0.70	0.70	0.78	0.56	0.54
1000	L	1.01	0.76	0.78	0.59	0.70	0.78	0.76	0.60	0.55	0.62
15/52/33	U	0.61	0.66	0.58	0.54	0.63	0.65	0.72	0.76	0.62	0.66
2000	L	0.87	0.76	0.82	0.64	0.66	1.04	0.94	0.80	0.68	0.74
15/52/33	U	1.08	0.98	0.84	0.94	0.82	0.78	0.81	0.76	0.76	0.72
3000	L	0.90	0.79	0.82	0.74	0.71	0.42	0.46	0.42	0.41	0.50
30/0/70	U	0.98	0.90	0.74	0.60	0.66	1.09	1.04	1.02	0.76	0.86
1000	L	0.81	0.62	0.56	0.45	0.52	0.84	0.80	0.60	0.47	0.68
30/0/70	U	1.05	0.99	0.95	0.68	0.75	0.86	0.88	0.86	0.52	0.78
2000	L	0.87	0.80	0.88	0.68	0.72	0.97	0.82	0.82	0.82	0.94
Control	U	0.95	0.86	0.81	0.86	0.85	0.87	0.79	0.75	0.80	0.84
	L	0.65	0.51	0.57	0.62	0.57	0.92	0.82	0.73	0.81	0.78

*Mean values for PI and PII.

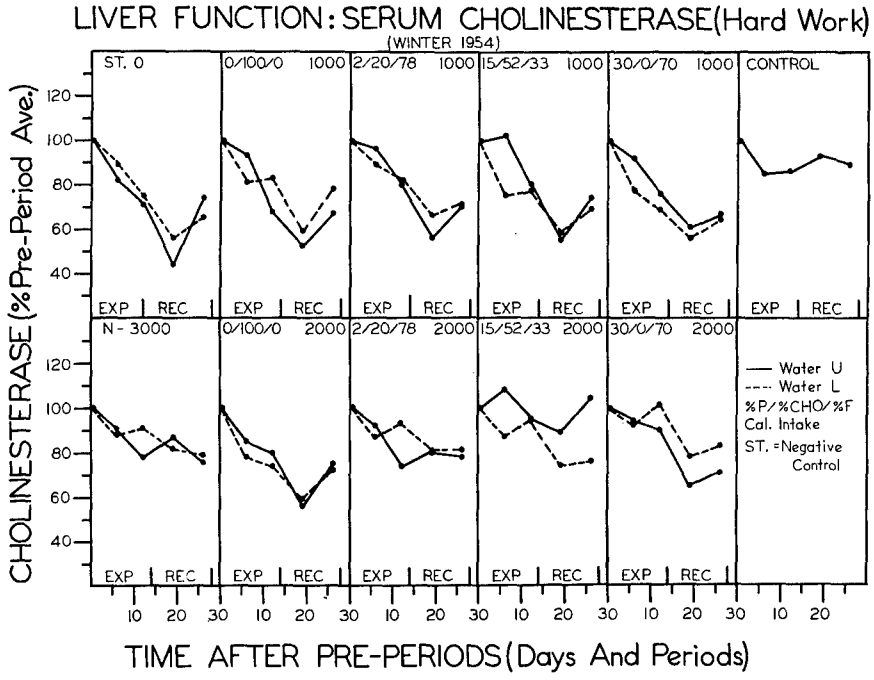


FIGURE III. 31

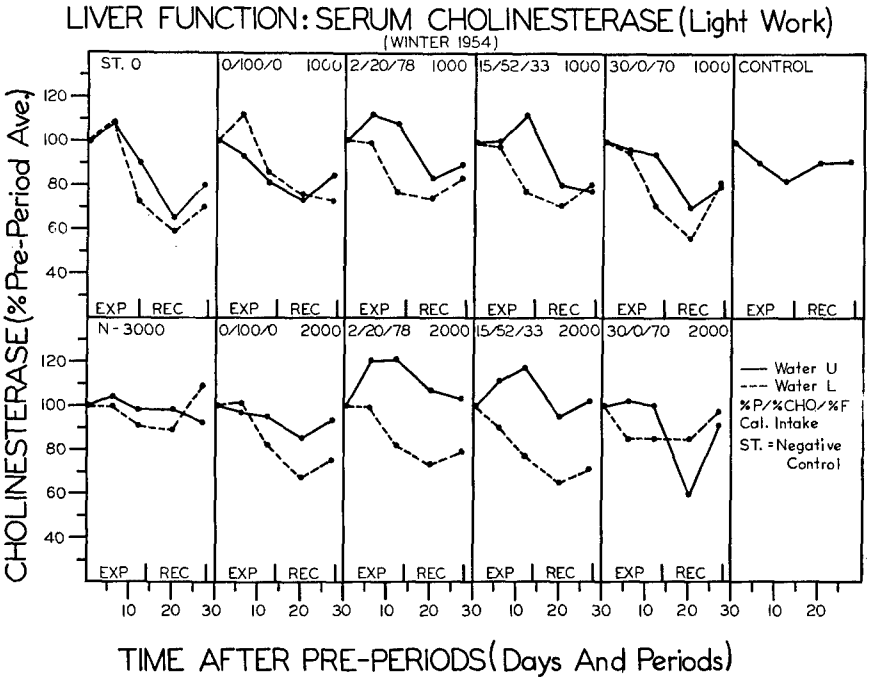


FIGURE III. 32

TABLE III. 67

PRE-PERIOD DATA ON SERUM TOTAL CHOLESTEROL
(mg/100 ml)

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
Flight 1	250	36	14.4	221	52	23.5
Flight 2	198	44	22.2	189	32	16.9
Flight 3	182	47	25.8	186	45	24.2
Flight 4	120	40	33.3	209	43	20.6
Controls	210	45	21.4	197	54	27.4

TABLE III. 68

SERUM TOTAL CHOLESTEROL
(mg/100 ml)

Experimental Regimen		Hard Work Pre*	Exp I	Exp II	Rec I	Rec II	Light Work Pre*	Exp I	Exp II	Rec I	Rec II
ST 0	U	265	206	183	200	191	202	194	209	218	204
	L	206	225	236	220	206	205	230	218	200	225
0/100/0	U	227	170	179	192	194	187	168	174	185	176
1000	L	199	241	203	184	210	153	162	196	190	206
0/100/0	U	198	167	132	175	198	170	154	188	168	226
2000	L	196	146	195	178	208	192	162	186	220	188
2/20/78	U	217	226	180	170	236	142	155	170	185	184
1000	L	207	228	146	196	204	160	185	220	222	216
2/20/78	U	204	200	176	178	240	116	164	182	172	198
2000	L	216	192	208	173	226	125	182	156	210	175
15/52/33	U	205	166	180	195	208	194	252	218	172	191
1000	L	161	182	182	186	194	129	220	246	215	212
15/52/33	U	204	217	195	155	224	178	174	179	158	178
2000	L	184	221	242	194	204	143	210	182	190	186
15/52/33	U	209	136	180	205	196	222	248	223	257	228
3000	L	194	254	175	152	205	168	184	173	185	202
30/0/70	U	218	200	166	235	230	196	232	212	218	198
1000	L	198	234	229	206	230	168	180	204	195	191
30/0/70	U	233	226	168	205	214	235	184	209	180	218
2000	L	163	190	242	199	206	181	225	182	175	195
Control	U	245	160	204	208	206	152	187	205	227	206
	L	229	215	219	168	199	187	236	191	205	197

*Mean values for PI and PII.

Wet Weight of Feces. Fecal weight is presented summarily in Table III. 69. In general, the results were similar to those obtained in the temperate study of 1953. During experimental regimens, there was a correlation between mean daily fecal weight and mean daily caloric intake; the least fecal production was during starvation. During pre- and recovery period, the weights ranged between 75 and 275 gm/day. The values for the second weeks of pre- and recovery periods tended to be somewhat smaller than for the first weeks.

A finding not reported for the temperate study but observed in the present study was a marked effect of dehydration on mean daily fecal weight. In the 20 paired comparisons shown in the table, dehydration diminished the fecal weight in both experimental weeks in fifteen, and in either the first week or the second in three. Only in 30/0/70 2000 hard work and 0/100/0 2000 hard work did dehydration have no diminishing effect.

Fecal Fat. Daily fecal fat output was calculated from data on the fecal fat in the seven-day pooled fecal specimens. The pre-period values (Table III. 70) are entirely normal and similar to those reported previously (Sargent et al., 1954).

The mean daily output of fecal fat was correlated closely with the output of feces. The data summarized in Table III. 71 point up several general trends. (1) During EXP I and EXP II limitation of water was correlated with a lower output of fat. (2) The output of fecal fat was greater on the 2000-Calorie regimens than on the 1000-Calorie. (3) There was no evidence that a high proportion of fat in the diet (2/20/78 and 30/0/70) caused an abnormal output of fat in the feces. (4) During REC I there was a greatly increased excretion of fecal fat. (5) In REC II the values were similar to those for the pre-period. (6) Work was not correlated with differences in fecal fat. The general results support those of 1953: a high fat diet of the type used in survival rations does not cause abnormal outputs of fecal fat or steatorrhea.

Dietary protein and fecal fat: Magee and his associates (Magee, Kim, and Ivy, 1953; Magee, 1954) have recently reported that in the dog and rat isocaloric substitution of carbohydrate by such purified proteins as casein, gelatin, and zein will significantly decrease the output of fecal fat. The mechanism of this phenomenon has not been established (Magee, 1954). The data collected in 1953 and 1954 from our human subjects have been scrutinized in this respect (Table III. 72) and we find no evidence that isocaloric substitution of protein for carbohydrate significantly altered the daily output of fecal fat. During the second week of a two-week period, the fat content of the feces did not change appreciably when the composition of the diet was changed from 2/20/78 to 30/0/70. However, appreciably more fat was eliminated when the nutrient mixture contained 70 and 78% fat than when it contained 0% fat. A similar effect of dietary fat can be seen in the tabular data of Magee, Kim and Ivy (1953). These conflicting results raise two questions: (1) Is the phenomenon characteristic only of rats and dogs? (2) Is the phenomenon provoked only by isocaloric substitution of purified proteins?

Benzidine Reaction. In a previous report (Sargent et al., 1954) attention was called to the high frequency of strongly positive benzidine reactions on fecal specimens collected from men subsisting on the 5-in-1 ration. Preliminary study of the phenomenon implicated the components of ration containing highly processed beef products as the cause of the positive reactions.

The seven-day fecal specimens of the present investigation were routinely tested for the presence of benzidine-positive substances. The results obtained (Table III. 73) are in close agreement with the 1953 data. The incidence of positive reactions was over four times greater among specimens collected while the men were on the 5-in-1 ration than while men were on the several experimental regimens none of which contained 5-in-1. Only three +3 reactions were noted among 84 specimens of the experimental periods: two were from men on 2000 Cal/day of meat bar and one from a subject on 3000 Cal/day of meat bar, crackers, raisins, and catsup. When the subjects changed from the 5-in-1 ration (REC I) to the A ration (REC II) there was no significant change in the distribution of positive reactions. This finding does not actually contradict our previous conclusions, for in REC II the subject ate very large quantities of food including beef products. Caloric intakes ranged between 6000 and 8000 Cal/day. Thus, the two periods are not strictly comparable.

The results of the 1953 study suggested that the experimental diet modified the distribution of positive reactions in REC I. The meat bar and cereal biscuit regimen was followed by no reactions in REC I greater than +1. The experimental diet had no influence on the benzidine reaction of REC I during these trials (Table III. 74).

Muscle Fibers. Microscopic examination of all fecal specimens was performed. The principal element studied was the muscle fiber: the quantity per high power field (X150) and the proportion of undigested and digested fibers. The degree of digestion was judged by standard clinical pathological criteria (Hepler, 1949).

Number of fibers: Observations on the number of fibers per high power field are summarized in Table III. 75. Several points of interest should be noted. (1) The pre-period values agree with those reported from the control study of 1953. (2) The subjects' feces tended to contain fewer fibers in the experimental periods than in the pre-periods. (3) The recovery periods were characterized by lower counts than the pre-periods. For the hard work groups the grand mean was 7.4 for the pre-periods and 5.2 and 4.6 for REC I and REC II, respectively, for the light work groups the means were 6.8, 3.6, and 4.8 respectively.

In order to test whether these trends were independent of the weight of feces passed and the volume to which the feces were diluted during the pooling of the seven-day specimens, a correction was made in the counts per high-power field. The specimens were prepared for microscopic examination in such a way that uniformity of thickness was approximated: one or more drops of fecal suspension were placed on a glass slide and spread under a cover slip by gentle pressure. In making the weight-volume correction, it was assumed that

the number of fibers in a uniformly deep field of constant area had been estimated; that is, the volume of the fecal suspension examined was constant. No numerical value was assigned to the volume, but the quantity of fibers per high-power field was further assumed to represent the number per unit volume. The number of fibers counted was then multiplied by the dilution factor (volume to which pools had been made up) and divided by weight of feces in pool. Thus, the fiber count was converted to number of fibers per gram of feces. When the volume and weight were expressed as ml/day and gm/day, the count became number/gm/day. The number, however, was only an index for no attempt was made to estimate the volume of the fecal specimen microscopically examined. The calculated index numbers are summarized in Table III. 75.

The index numbers do not show the trends mentioned earlier with regard to the recovery periods. There still, however, is tendency for the fecal fibers to become less numerous in the experimental periods. This trend is more consistent for the hard work groups than for the light work ones. The nutrient mixtures most uniformly associated with the reduction are 15/52/33 1000 and 2000. At 3000 Cal/day, there is little variation from pre-periods to the experimental periods. The 2/20/78 2000 regimen was correlated with small index numbers in all four pairs of subjects but the 1000-Calorie regimen was associated with larger increases in the numbers. Rather erratic results are noted among the men on 30/0/70. The low residue regimens -- ST 0 and 0/100/0 1000 and 2000 caused less uniform decreases than might have been anticipated.

The most striking finding is the trend to low index numbers in REC I. The means for the pre-periods are 53 for the hard work group and 52 for the light. In REC I, the means are 25 and 24, respectively. In REC II, the means are 49 for both groups. Thus the low count in REC I was independent of volume and weight of feces but the low count for REC II was caused by increased dilution of the feces.

Digestion of fibers: The condition of the fecal muscle fibers has an important bearing on the interpretation of the variations in the quantity of fibers. In this way, furthermore, information may be gleaned regarding the digestability of the several rations. At the time of microscopic examination, an estimate was made of the distribution of digested, partially digested, and undigested fibers in each fecal specimen. On the basis of predominant type, the specimens were classified according to the following digestion-spectrum: undigested, undigested-partially digested, undigested-digested (approximately 50-50) and digested (Table III. 76A). A few specimens contained no muscle fibers. These were not included in the statistical analyses of the distributions (Table III. 76B).

The observations summarized in Table III. 76 bring out three significant facts. First, in contrast to the pre-period, fecal specimens collected during the experimental periods contained large numbers of undigested muscle fibers. This finding confirmed an impression gained by Mrs. Enid Meltzer from her studies of the 1953 specimens (Sargent et al., 1954). The most noteworthy trends were for the 15/52/33 regimen where 19 of 34 specimens were "undigested" and only 8 were "digested" and for the 0/100/0-regimen where 9 of 16 specimens

were "undigested" and only 3 were "digested." According to the Chi-Square test, the differences between the pre- and experimental periods were highly significant. Second, in REC I there was a greater number of undigested specimens than in the pre-period even though fewer specimens were available for study. The trend was confirmed by statistical treatment of the data but the P lay between the 5 and 10% levels. Third, in REC II, the number of "undigested" specimens decreased markedly. When compared to the pre-period there was a suggestive difference by X^2 test for P was between the 5 and 10% levels. When compared to REC. I, the statistical significance increased: P now was between the 1 and 5% levels.

In substance then, we deal with marked shifts in appearance of the fecal muscle fiber. Considering the pre-period as the base line, undigested fibers predominate in the experimental periods, a relatively large number of specimens contain undigested fibers in the first week of recovery, and in REC II there were relatively few specimens in the "undigested" category.

General comments on fecal muscle fibers: Two general facts have been established: (1) There was a marked reduction in the number of fibers in fecal specimens collected during REC I. (2) There were significant variations in the degree of digestion of the fibers among the three phases of the investigation. Since there was relatively little diarrhea among the subjects we can assume that the shifts are more closely correlated with digestibility than with the rate at which the gastrointestinal contents traversed the length of the gut. In the experimental periods the wide variations in the number of fibers make rigorous interpretation difficult. The tendency for undigested fibers to predominate both in low nitrogen and high nitrogen regimens suggests an impairment of digestion -- decreased activity of proteolytic enzymes due either to (1) reduced function of pancreas or (2) deviation from optimal milieu for enzymatic activity. In the case of the high nitrogen regimen reduced digestibility of the meat bar may also be a factor. In REC I the evidence points to two processes. (1) The great reduction in the number of fibers passed (both absolute and relative) indicates increased enzymatic activity to meet the anabolic demands of rehabilitation. (2) That enzymatic processes had not fully recovered from the stresses of the experimental phases is suggested by the fact that there were relatively more undigested fibers in the specimens than had been present during the pre-periods. The relative increase in the number of fibers, however, may merely reflect the increased intake of protein by the subjects. This latter interpretation is doubtful, however, for in REC II the relative number of undigested muscle fibers decreased even though the dietary intake continued to rise. Two processes may account for the relative improvement in REC II. (1) Full recovery of enzymatic processes or (2) increased digestibility of protein from A ration in comparison to the 5-in-1 proteins. On the basis of the data available it is impossible to assign relative importance to these two possible factors.

The most intriguing point is that by means of careful qualitative analysis evidence has accrued which suggests that significant alterations occur in the digestive processes of castaways, and a question now rises on the relative digestibility of highly processed foods such as occur in the components of military rations. These matters deserve careful scrutiny. Impaired physiology

of digestion robs the castaway of what little he may be given in his survival ration.

Serum Amylase. Amylase is an enzyme produced by the parotid gland and the acinar cells of the pancreas. The level of this enzyme in the blood (serum) has been correlated with severe disorders of the parotid glands (mumps) and the pancreas (mumps, pancreatitis). In such disorders the serum level may rise to as high as 1000 amylase units/100 ml. Normally the level fluctuates between 50 and 200 units. Bodansky and Bodansky (1952) point out that any value exceeding 200 units should arouse suspicion of pancreatic dysfunction. The causes of fluctuations with the normal range have not been elucidated.

In the five groups of subjects studied essentially normal values for serum amylase were found during the pre-periods (Table III. 77). The mean levels ranged from 46 ± 9.0 to 128 ± 38.1 units. The coefficients of variation ranged from 19.5 to 55.3%. This great variability makes it difficult to interpret variations in serum amylase which fall within the range 50-200 units. Indeed on examination, only one consistent trend was evident in the mean weekly data for the six-week period (Table III. 78); namely, a tendency for the serum amylase to rise in the first week of recovery. This rise was most marked in the case of nutrient mixtures high in fat (2/20/78 and 30/0/70) and starvation. No consistent influence of water intake or work load was evident. The control subjects did not experience the recovery-period rise.

To examine further the variations in serum amylase, all men were selected who, at any time in the course of the investigation, had a serum amylase of 200 or more units. Seventeen such subjects were identified (Table III. 79). These seventeen men contributed 23 values of 200 or more: 4 (17.4%) in the pre-periods, 3 (13.1%) in the experimental periods, and 16 (69.5%) in the recovery periods. Fifteen of the 16 values in recovery fell in the first period of recovery.

In the experimental period, one man (No. 2) had a value of 205 in EXP II of starvation and one (No. 85) had values of 355 and 408 in EXP I and EXP II, respectively, while on 15/52/33 2000. Since both these men had had values exceeding 200 once during the pre-periods it may be that they were suffering from subclinical pancreatic disease or that they were merely individuals who normally had high serum levels for amylase. Two other subjects (No. 14 and No. 59) had values of 200 and 203 in the pre-periods.

The definite increase in incidence of high serum amylase values in the recovery period is reminiscent of the findings for serum cholinesterase. It was observed that the decrease in serum cholinesterase was always greatest, when it occurred, in the first week of recovery. It was concluded that this phenomenon represented a lag in the reaction of the liver to the experimental regimen.

Three experimental regimens were closely correlated with the high incidence of serum values exceeding 200; viz., starvation, 70% fat, and 78% fat.

Nutrient Mixture	Total Subjects	Serum Amylase: 200 units or more No. Subjects	% of Total Subjects
ST 0	14	4	28.6
2/20/78 1000	8	4	50.0
2/20/78 2000	8	3	37.5
30/0/70 1000	8	1	12.5
30/0/70 2000	8	2	25.0
0/100/0 2000	8	1	12.5

One man showed a high value after coming off 0/100/0 2000. In the winter of 1953 one subject developed what was thought to be biliary dyskinesia while subsisting on the 70% fat diet. Like the above subjects, the maximal rise in serum amylase did not appear until the recovery period. This consistent finding suggests that a high fat diet does indeed disturb normal pancreatic function and may lead to disabling clinical manifestations.

TABLE III. 69

FECAL WET WEIGHT
(gm/day, average)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	187	156	35	25	291	209	106	68	10	42	95	159
	L	145	125	13	13	210	128	113	103	16	17	214	190
0/100/0	U	129	95	39	81	199	244	119	106	27	60	119	109
1000	L	197	134	14	14	225	181	77	109	30	30	112	115
0/100/0	U	165	39	55	41	275	167	153	128	36	36	145	158
2000	L	151	125	60	57	236	205	184	92	25	47	117	152
2/20/78	U	169	120	73	49	263	135	123	111	67	29	203	153
1000	L	99	33	25	32	112	77	135	55	19	19	125	76
2/20/78	U	182	219	115	87	275	161	171	170	99	41	242	181
2000	L	161	137	45	45	302	169	103	79	29	29	75	109
15/52/33	U	187	105	57	69	263	166	231	129	159	95	237	214
1000	L	165	99	19	25	109	85	125	123	32	32	107	99
15/52/33	U	106	91	50	54	264	143	141	105	191	59	177	139
2000	L	199	93	45	25	215	168	99	119	50	50	141	151
15/52/33	U	207	147	159	131	175	154	111	134	123	107	275	114
3000	L	146	129	88	87	141	185	78	79	85	85	113	139
30/0/70	U	99	115	114	93	271	303	196	87	38	79	185	125
1000	L	163	131	33	33	215	172	215	95	44	44	146	241
30/0/70	U	77	94	54	31	145	76	129	107	79	83	183	136
2000	L	93	83	57	39	233	167	132	74	65	65	69	207

TABLE III. 70

PRE-PERIOD DATA ON FECAL FAT
(gm/day)

Flight	Pre-Period	M	s.d.	C.V.
1	I	6.5	2.9	45
	II	4.4	1.9	43
2	I	5.5	1.7	31
	II	3.5*	1.0*	29*
3	I	5.1	1.6	31
	II	4.0	2.3	58
4	I	4.1	1.6	39
	II	3.2	1.2	37

*These values were calculated excluding an extremely high fat output of 15 gm/day. If this value is included, M, s.d., and C.V. become 4.1, 2.6, and 66, respectively.

TABLE III. 71

TOTAL FECAL FAT
(gm/day)

Experimental Regimen		Hard Work					Light Work				
		Pre*	Exp		Rec		Pre*	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	5.6	0.6	0.5	14.7	7.0	3.1	0.5	1.5	6.6	5.2
	L	5.1**	0.5	0.5	14.7	5.4	3.4	0.3	0.4	8.1	6.6
0/100/0	U	4.6	3.2	2.0	8.4	9.5	3.3	0.4	0.6	4.6	3.2
1000	L	5.8	0.5	0.5	13.3	4.3	3.3	0.5	0.5	6.6	5.6
0/100/0	U	5.8	0.8	1.6	16.4	10.0	5.3	0.8	0.8	7.5	8.2
2000	L	4.6	0.8	0.8	11.5	5.0	3.8	0.7	0.8	7.6	4.8
2/20/78	U	5.9	2.4	1.6	14.1	3.3	7.2	3.4	1.9	15.1	7.5
1000	L	4.0	1.6	2.2	12.4	3.5	3.8	1.5	1.5	5.8	2.3
2/20/78	U	7.8	3.8	3.0	19.3	4.9	5.5	2.9	2.7	15.2	4.8
2000	L	5.2	1.2	1.2	19.7	5.4	3.6	1.6	1.6	2.5	2.5
15/52/33	U	6.2	1.5	1.6	11.7	8.0	3.2	1.3	1.5	11.9	5.8
1000	L	3.5	0.8	1.1	6.2	3.4	3.2	0.7	0.7	4.3	2.9
15/52/33	U	5.7	1.5	1.2	13.5	6.7	2.8	1.9	0.9	4.4	5.7
2000	L	6.0	1.6	0.7	16.1	7.7	4.5	1.5	1.5	8.7	3.4
15/52/33	U	6.7	4.0	2.8	8.3	6.3	4.9	2.8	2.2	15.8	4.7
3000	L	4.4	3.8	3.0	7.6	5.0	2.8	2.8	2.8	5.4	2.2
30/0/70	U	4.6	2.2	2.1	11.3	8.2	4.8	1.2	3.0	9.6	4.3
1000	L	4.0	0.8	0.8	9.8	3.9	3.9	1.3	1.3	5.0	4.8
30/0/70	U	3.1	2.2	1.1	7.9	4.7	6.1	2.9	2.6	13.1	4.5
2000	L	3.3	2.4	1.5	10.8	7.1	3.8	2.6	2.6	2.7	4.8

*Mean values for PI and PII.
**Excluding an unusually high value of 15 gm/day.

TABLE III. 72

PROTEIN CONTENT OF DIET VS. FECAL WEIGHT AND FECAL FAT IN EXP II

Experimental Regimen	1953		1954	
	Fecal Weight gm/day	Fecal Fat gm/day	Fecal Weight gm/day	Fecal Fat gm/day
0/100/0 1000	50	1.4	46	0.9
2/20/78 1000	36	2.9	32	1.8
30/0/70 1000	72	3.4	62	1.8
0/100/0 2000	59	1.4	43	1.0
2/20/78 2000	41	3.1	50	2.1
30/0/70 2000	54	3.2	52	2.0

TABLE III. 73

EFFECT OF 5-IN-1, GARRISON, AND EXPERIMENTAL RATION COMPONENTS ON FECAL BENZIDINE REACTION

Ration	Stools Tested No.	Intensity of Benzidine Reaction 0	tr	+1	+2	+3	+4	% Positive
Fasting	7	7	0	0	0	0	0	0
Jelly bar, spice drops, hard candy	16	15	1	0	0	0	0	6
Meat bar	17	10	2	3	0	2	0	41
Crackers and oleomargarine	17	16	1	0	0	0	0	6
Meat bar, crackers, raisins, catsup	34	29	3	1	0	1	0	15
Total	84	70	7	4	0	3	0	17
5-in-1 (pre-period)*	141	29	13	36	27	29	7	79
5-in-1 (recovery)*	80	24	13	14	13	11	5	70
A ration (recovery)*	87	27	19	17	13	11	0	69

*PI & II vs. REC I: $X^2 = 6.82$; not significant at 5% level.
REC I vs. REC II: $X^2 = 6.25$; not significant at 5% level.

TABLE III. 74

RELATIONSHIP BETWEEN PRECEDING DIET AND FECAL BENZIDINE REACTION DURING SUBSEQUENT RECOVERY

Experimental Combination	Intensity of Benzidine Reaction in Rec I 0	tr	+1	+2	+3	+4
Fasting	4	0	1	1	3	0
Jelly bar, spice drops, hard candy	3	2	3	4	1	2
Meat bar	5	4	1	1	1	1
Crackers and oleomargarine	3	3	5	3	0	1
Meat bar, crackers, raisins, catsup	8	5	4	2	5	1

TABLE III. 75

FECAL MUSCLE FIBERS

Experimental Regimen		No./H. P. F. Hard Work Pre*	Exp I	Exp II	Rec I	Rec II	No./H. P. F. Light Work Pre*	Exp I	Exp II	Rec I	Rec II	Index No./gm of feces/day Hard Work Pre*	Exp I	Exp II	Rec I	Rec II	Index No./gm of feces/day Light Work Pre*	Exp I	Exp II	Rec I	Rec II
ST 0	U	11	1	0	5	8	8	-	7	2	5	54	14	0	20	56	73	-	110	19	52
	L	7	8	8	6	4	6	1	1	5	6	57	62	62	30	51	51	15	15	20	47
0/100/0	U	8	4	7	7	3	11	0	1	7	4	69	69	63	37	21	95	0	8	58	48
1000	L	9	-	-	3	4	5	4	4	1	3	48	--	--	14	37	51	61	61	9	42
0/100/0	U	10	1	1	6	3	11	0	0	2	5	62	10	10	25	30	79	0	0	14	49
2000	L	10	1	1	2	5	8	2	5	1	8	72	8	8	9	41	51	54	68	8	73
2/20/78	U	4	6	6	6	4	8	18	0	3	5	28	58	84	26	49	61	141	0	16	54
1000	L	4	-	-	-	3	2	4	4	3	2	39	--	--	--	44	17	147	147	24	32
2/20/78	U	13	2	4	4	5	10	3	2	4	6	79	16	43	17	51	75	29	45	21	56
2000	L	6	1	1	14	3	3	1	1	2	2	41	10	10	54	30	28	12	12	25	23
15/52/33	U	7	2	2	3	8	5	2	3	4	4	48	25	20	13	80	29	10	23	18	32
1000	L	7	1	1	1	5	6	2	2	4	7	64	44	6	8	92	48	28	28	36	86
15/52/33	U	5	2	2	5	1	8	4	4	3	6	48	28	26	21	12	64	17	61	17	71
2000	L	6	0	0	6	6	6	6	6	4	7	41	0	0	30	60	53	57	57	28	77
15/52/33	U	10	5	4	6	6	8	10	12	9	4	58	32	30	35	65	64	62	85	37	57
3000	L	8	1	3	1	3	4	5	5	2	2	58	11	32	7	27	30	30	30	17	21
30/0/70	U	7	1	2	3	3	8	2	2	2	2	59	5	20	12	18	47	15	18	11	26
1000	L	8	1	1	8	8	9	11	11	1	6	48	11	11	40	78	54	83	83	9	43
30/0/70	U	2	3	4	7	2	7	2	2	11	4	22	32	84	49	42	58	18	28	63	48
2000	L	6	1	1	6	9	1	6	6	2	7	65	10	18	28	90	9	35	35	23	41

*Mean values for PI and PII.

TABLE III. 76

DIGESTION OF FECAL MUSCLE FIBERS

A. FREQUENCY DISTRIBUTION

Dietary Regimen	No. of Specs.	Predominant Type of Fiber Undigested	Undigested-Partially Digested	Undigested Digested	Digested	Fibers Absent
Starvation	7	1	0	1	2	3
Spice drops, starch jelly bar, hard candy	16	9	0	0	3	4
Meat bar	17	5	0	5	6	1
Crackers and oleomargarine	17	6	0	1	6	4
Meat bar, crackers, catsup, raisins	34	19	0	2	8	5
Total Experimental	91	40	0	9	25	17
5-in-1 (pre-period)	141	15	8	20	98	0
5-in-1 (recovery)	80	18	1	9	52	0
A ration (recovery)	87	7	0	10	70	0

B. STATISTICAL ANALYSES

Test	X^2	Significance
Pre I & II vs. Exp I & II *	50.06	$P < 0.001$
Pre I & II vs. Rec I	6.93	$0.10 < P > 0.05$
Pre I & II vs. Rec II	6.52	$0.10 < P > 0.05$
Rec I vs. Rec II	8.13	$0.05 < P > 0.01$

*Specimens with no fibers excluded in analysis.

TABLE III. 77

PRE PERIOD DATA ON SERUM AMYLASE

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
Flight 1**	82	27.4	33.5	122	46.1	37.8
Flight 2**	67	15.2	22.6	99	28.2	28.4
Flight 3**	67	37.0	55.3	120	34.2	28.5
Flight 4**	128	38.1	29.8	46	9.0	19.5
Controls*	53	24.2	46.7	81	26.4	32.6

*Differences between means significant at 2% level.

**Differences between means significant at 1% level.

TABLE III. 78

PANCREATIC FUNCTION: SERUM AMYLASE

Amylase Units

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	103	132	93	132	247	171	57	119	33	75	94	61
	L	80	84	103	54	185	76	137	44	114	102	190	125
0/100/0	U	72	136	85	87	128	105	48	106	32	70	126	81
1000	L	68	112	125	60	137	60	122	32	146	136	134	114
0/100/0	U	58	152	60	68	122	116	30	113	41	70	124	58
2000	L	69	96	94	53	186	104	144	48	158	184	145	120
2/20/78	U	91	151	100	90	224	115	45	114	47	66	118	78
1000	L	68	72	72	40	174	107	115	48	140	128	221	150
2/20/78	U	84	108	75	78	153	107	73	162	53	120	181	77
2000	L	66	92	65	46	202	98	132	50	106	101	132	113
15/52/33	U	64	78	66	66	132	94	88	116	56	134	128	84
1000	L	62	118	96	60	184	126	126	50	138	130	148	126
15/52/33	U	116	164	111	126	166	98	88	114	45	106	118	66
2000	L	51	120	85	63	122	68	162	45	235	255	112	108
15/52/33	U	52	88	84	58	86	48	116	132	112	161	130	106
3000	L	55	108	100	84	156	69	84	52	75	120	79	107
30/0/70	U	66	109	72	70	186	122	49	98	64	106	134	65
1000	L	88	128	111	59	130	100	156	46	116	136	190	140
30/0/70	U	96	110	94	108	177	132	78	126	42	111	150	82
2000	L	46	90	95	49	156	94	101	47	152	134	157	128
Control	U	71	112	86	57	104	44	50	68	64	85	55	65
	L	43	91	68	65	103	74	49	53	62	92	50	64

TABLE III. 79

NUTRIENT MIXTURES ASSOCIATED WITH SERUM AMYLASE VALUES IN EXCESS OF 200 UNITS

Experimental Nutrient Mixture		Subject Code No.	Serum Amylase Pre I	Pre II	Exp I	Exp II	Rec I	Rec II
ST 0		1	142	170	190	---	277	223
		2	100	205	162	205	217	190
		4	106	77	68	73	277	152
		26	82	103	140	73	263	102
0/100/0	2000	30	73	131	107	68	300	159
15/52/33	2000	85	232	65	355	408	150	115
30/0/70	1000	10	77	68	82	72	203	128
30/0/70	2000	11	128	170	133	150	277	195
		77	152	47	132	140	203	136
2/20/78	1000	14	119	200	131	111	277	128
		35	77	77	90	44	203	103
		59	26	203	47	82	125	16
		79	103	50	172	132	205	159
		80	127	47	107	125	237	140
2/20/78	2000	37	65	133	65	47	203	111
		38	68	50	65	44	200	86
		61	125	---	68	157	237	132

3. Respiratory Function

Analysis of Data from 1953. Several points of substantial interest have emerged from detailed analysis of the data obtained in the pilot study of 1953 and opportunity is taken here to report some of these findings. For the most part, this section has been written by Dr. W. A. Boyd (1954). All details of methodology and the actual data were reported by Sargent et al. (1954).

The salient and potentially important results from this detailed statistical study of the resting metabolism were:

a) A diminished pulmonary output of carbon dioxide during dietary regimens whose composition deviated markedly from the normal diet of the North American population.

b) A decreased pulmonary exchange simultaneously with the carbon dioxide retention.

c) A lowered oxygen consumption on all low calorie diets, the greatest decrease occurring in pure carbohydrate regimens, and the least in high protein regimens. There was a dissociation between the lowering of oxygen consumption

and the carbon dioxide consumption, the implication being that different metabolic pathways are affected to bring about the two sets of results.

d) No effect of chronic dehydration on any of the respiratory measurements.

The evidence upon which the above statements rest follows. In tables and charts of this section the diets have been separated into two classes: the "normal" mixture and the "abnormal" mixture diets. The "normal" mixture group consists of the diets of 15% protein, 52% carbohydrate and 33% fat at the three caloric levels studied, where all distributions refer to percentage of total calories. The "abnormal" mixture group includes the remainder of the diets studied.

The division of the diets into "normal" and "abnormal" was based on data for the average distribution of calories voluntarily selected by North American ground troops from the garrison ration (Johnson and Kark, 1946). This distribution (15/52/33) is also very close to the average distribution of calories in the diets of North American civilians. Any diet differing from this distribution of calories, such as pure carbohydrate, was therefore considered "abnormal". Starvation was also classed as an abnormal diet for two reasons: (1) the subjects were eating nothing and (2) the energy was derived almost entirely from fat and protein.

In the following tables on statistical analyses, no P value over 0.10 has been recorded. If, upon analysis, a P value over 0.10 was obtained, "n.s." has been written in the table. In many cases inspection of the data indicated insignificance; these instances have been represented by a dash (-) in the tables. The symbols to be used throughout the tabular presentation of the data are found in Table III. 80. The U and L refer to unlimited water (ad libitum) and limited water (900 ml/man/day in Phase I and 910 ml/man/day in Phase II), respectively.

The data for the resting carbon dioxide production are found in Tables III. 81 and 82. The only significant result obtained was a decreased production of carbon dioxide during Week II of the experimental period on the abnormal mixtures. It appears that this phenomenon begins in Week I of the experimental period but is not of sufficient magnitude to be significant. This trend then becomes exaggerated in Week II and becomes highly significant.

These experimental data do not give evidence of the mechanism involved in the carbon dioxide "retention," by which term is meant a significant relative reduction in pulmonary output of carbon dioxide. There are three possible means by which such retention might be brought about: (1) decreased carbon dioxide production by the metabolizing tissue, (2) decreased carbon dioxide transportation, and (3) increased carbon dioxide fixation. Of these three only alterations in carbon dioxide transport can be discussed in the light of available observations.

That carbon dioxide transport might be involved in the retention is suggested by other measurements made during this study. Among the abnormal mixtures are those rations -- ST 0 and 30/0/70 -- which produce metabolic

acidosis (ketogenesis). A disturbance of the acid-base balance resulting in metabolic acidosis would decrease the carbon dioxide content of the blood and the carbon dioxide capacity of the plasma, since a portion of the "base" normally available for carbon dioxide transport is lost or bound by excess organic acid. From the total titrable acidity and pH of the urine, it was known that the most striking increase in the titrable acidity and decrease in urinary pH occurred on the ketogenic diets. Measurement of urinary ammonia plus qualitative and quantitative tests for urinary acetone bodies confirm the existence of metabolic acidosis.

One further piece of evidence indicating that the transportation of carbon dioxide might be involved in the observed carbon dioxide retention is seen in Table III. 85. Resting pulmonary ventilation was significantly reduced only in Week II when there was a significant carbon dioxide retention. Inasmuch as the respiratory center is greatly influenced by carbon dioxide, the decrease in pulmonary ventilation can be correlated with a low carbon dioxide content of the blood.

The evidence available, however, does not completely support the hypothesis that the carbon dioxide transportation mechanism is involved in the carbon dioxide retention. The abnormal mixture also contains the pure carbohydrate diets which are anti-ketogenic. Statistical analysis of the ketogenic and anti-ketogenic diets with respect to their effect on carbon dioxide retention yielded nothing significant, indicating that the anti-ketogenic diets also caused carbon dioxide retention.

Further experiments, in which the effect on the acid-base balance of these diets is studied by means of blood analyses, would give valuable data in assessing the role of the carbon dioxide transport mechanism of the observed carbon dioxide retention.

There was no apparent effect of calorie level or water limitation on this phenomenon. The method of treatment of the data; i.e., correction of surface area for water loss, would exaggerate any existing effect of dehydration.

The data on the mean oxygen consumption of the eight subjects are presented in Tables III. 83 and 84. It can be seen that there is a significant decrease in oxygen consumption in both weeks of the experimental period on the abnormal mixture. This reduction is restricted to the abnormal dietary group because of the weighted data comprising the abnormal and normal groups. It is apparent from Table III. 83 that all of the dietary mixtures with the exception of the 15/52/33 3000 and 30/0/70 2000 show a decrease in the oxygen consumption. The normal mixture group is prejudiced in favor of the 15/52/33 3000 regimen inasmuch as eight subjects were on this diet whereas only four subjects were on each of the other two regimens comprising the normal mixture group. Presumably, high specific dynamic action explained the results for 30/0/70 2000. In general, the data presented here are in agreement with the results of Keys et al. (1950) in that caloric limitation decreases the resting oxygen consumption. It is of further interest that the observations of Hervey and McCance (1952) in which the pure carbohydrate diet resulted in a lower oxygen consumption than starvation is also confirmed by these data. In fact, the oxygen consump-

tion at both caloric levels of the pure carbohydrate diet is lower than on any other dietary regimen. There were too few observations to analyze statistically for the effect of calorie limitation on any one diet. Again, it can be seen that water limitation did not have an effect on the gross oxygen consumption.

The mean energy expenditure for the eight subjects during the pre-period is in excellent agreement with the values reported by Passmore et al. (1952).

The different effects of the dietary regimens on carbon dioxide production and oxygen consumption shown in this study suggests a specific effect on each of the two phases of metabolism and not simply a decreased metabolism in general.

The data on the resting pulmonary ventilation on the eight subjects are found in Tables III. 85 and 86. The significance of the decreased pulmonary ventilation in Week II of the experimental period on the abnormal mixture has already been noted and a suggested explanation offered.

The phenomena described above are presented in graphic form, as averages for all subjects, for Week EXP II in three charts, one each for resting CO_2 (Figure III. 33), O_2 (Figure III. 34) and R.Q. (Figure III. 35).

Resting carbon dioxide production was lowest for the 1000-Calorie regimens, increasing with increasing caloric intake. So far as individual nutrients were concerned, the highest values for a given calorie intake were observed for the "normal" percentages (15% protein calories, 52% carbohydrate calories and 33% fat calories). At percentages much higher or much lower, our "abnormal" compositions, CO_2 production was less. That is to say, on abnormal mixtures there was "retention" of CO_2 in Week EXP II.

Resting oxygen consumption was lowest for the 1000-Calorie regimens, with one very high point for 30/0/70 2000, presumably a measure of the high specific dynamic action of this high protein regimen. Here an effect of specific nutrients may be detected. Oxygen consumption at a given calorie level tended to be lowest with low protein or fat percentages, and highest with high protein or high fat percentages, the reverse being true for carbohydrate percentages. This chart shows striking differences from that for carbon dioxide, in that the 15% protein, 52% carbohydrate and 33% fat do not show peculiarities for the oxygen consumption as they do for carbon dioxide production.

Another way to check the hypothesis that we are dealing with dissimilar metabolic mechanisms is to scrutinize the respiratory quotient (R.Q. = CO_2/O_2). If we were dealing only with a general decrease in metabolism during low calorie regimens, we should expect to find that at any given level of caloric intake, the R.Q. would change only with respect to specific nutrients, being lowest with high protein, low carbohydrate or high fat percentages. As Figure III. 35 shows, such is not precisely the case. At the 1000-Calorie level, there is a tendency in this direction, but no difference between 2% protein and 15%, or between 20% carbohydrate and 52%, or between 33% fat and 78%.

At the 2000-Calorie level, the "normal" percentages give the highest R.Q.'s in all cases. We are forced to conclude that "abnormalities" in percentage of calories from protein, carbohydrate, or fat, either above or below those considered "normal", leads to an abnormality of carbon dioxide production independent of any general metabolic effect as shown by the oxygen consumption or the R.Q.

These conclusions pose problem for further research of considerable theoretical and practical importance.

Results of Winter Study, 1954. All of the data for 1954 are given in Appendix II. Unfortunately, we cannot draw any conclusions with certainty. An entirely new method was employed, which had appeared satisfactory in preliminary trials. During the winter study of 1954 technical difficulties arose which were not detected until the results were calculated and analyzed statistically.

The unreliability of the data can be demonstrated by the results presented in Tables III. 87 and 88, in which the sedentary group on the normal mixture diets exhibit statistically significant decrease in pulmonary carbon dioxide production whereas the hard work flights on the abnormal mixture show no change at all. This finding is exactly opposite the observations obtained in 1953 and arose from the technical difficulties in 1954.

Oxygen consumption for 1954 showed trends similar to those obtained in 1953 in that the oxygen consumption for any pair of subjects tended to decrease during experimental periods and tended to be lowest in those regimens containing the least protein and the least calories (Tables III. 89 and 90). As in the case of carbon dioxide the data may be considered suggestive but not definitive because of technical difficulties.

The pulmonary ventilation data were the most reliable data obtained in 1954 (Tables III. 91 and 92). In general they agree with the resting pulmonary ventilation data obtained in 1953. The significant decrease found in the normal mixture group may or may not be real, the significant differences found between the limited and unlimited water groups are more likely due to technical factors rather than physiological ones.

Even though the results of 1954 were unenlightening concerning the effects of a complex experimental regimen (nutrient mixture, water, work, and cold) on the processes of metabolism, they gave much valuable information regarding the method employed. In all probability, with further research, the method employing meters in the determination of respiratory metabolism will become a practical one and permit large scale investigations such as the one attempted here.

Areas of Research. The interesting results obtained concerning the effect of the dietary mixtures on carbon dioxide production suggest that further research be done in this field. The acid-base balance should be studied in conjunction with the respiratory metabolism to elucidate the role played by the carbon dioxide transport system in the retention of carbon dioxide found in this study. Investigations at the cellular level would also be of interest as

to the nature of carbon dioxide production and carbon dioxide fixation by a metabolizing tissue taken from an organism maintained on an abnormal dietary regimen.

TABLE III. 80

SYMBOLS EMPLOYED IN STATISTICAL ANALYSES OF RESPIRATORY FUNCTION

Period	Symbol
Pre U	PU
Pre L	PL
Pre U & L	P
Exp I U	EIU
Exp I L	EIL
Exp I U & L	EI
Exp II U	EIIU
Exp II L	EIIL
Exp II U & L	EII
Exp I & II U	EU
Exp I & II L	EL
Exp I & II U & L	E
Hard Work	H
Sedentary	S

TABLE III. 81

MEAN RESTING CARBON DIOXIDE PRODUCTION: 1953
(ml/min/m^2, Corrected for Body Water)

Experimental Regimen		Pre	Exp I	Exp II	Rec
ST 0	U	123.5	124.2	105.5	143.2
	L	169.5	112.2	108.0	150.8
0/100/0	U	161.0	112.5	100.0	136.0
1000	L	132.5	102.5	91.5	149.0
0/100/0	U	137.0	110.0	99.0	144.0
2000	L	150.5	115.5	106.0	132.0
2/20/78	U	121.0	75.0	102.0	145.0
1000	L	192.0	96.0	97.0	190.0
2/20/78	U	151.0	116.0	110.0	163.0
2000	L	145.0	104.0	88.0	121.0
15/52/33	U	159.0	101.5	108.5	145.5
1000	L	137.5	102.0	96.5	151.5
15/52/33	U	135.0	124.0	104.0	-----
2000	L	128.5	122.0	119.5	147.5
15/52/33	U	150.5	144.8	134.2	136.2
3000	L	130.2	137.0	107.0	160.0
30/0/70	U	130.0	100.0	83.0	163.0
1000	L	129.0	111.0	112.0	167.0
30/0/70	U	154.0	115.0	115.0	166.0
2000	L	128.0	116.0	102.0	131.0

TABLE III. 82

NUTRIENT REGIMEN VS. RESTING CARBON DIOXIDE PRODUCTION: 1953
(Corrected for Body Water)

A. SUMMARY OF MEANS

Periods	CO_2 Production ml/min/m^2 Normal Mixtures	Abnormal Mixtures
PU	151	137
PL	132	153
P	140	145
EIU	129	112
EIL	128	109
EI	129	111
EIIU	125	102
EIIL	113	102
EII	119	102
EU	127	107
EL	121	106
E	124	106

B. STATISTICAL ANALYSES

Normal Mixtures			Abnormal Mixtures		
Test	X^2	P	Test	X^2	P
PU vs. PL	4.05	c.0.03	PU vs. PL	0.00	n.s.
EIIU vs. EIIL	5.90	c.0.05	-	-	-
PU vs. EIU	3.15	c.0.07	-	-	-
PU vs. EIIU	2.62	c.0.07	-	-	-
P vs. EI	0.07	n.s.	P vs. EI	8.84	0.02
P vs. EII	4.80	c.0.03	P vs. EII	16.03	<0.01

TABLE III. 83

MEAN RESTING OXYGEN CONSUMPTION: 1953

(ml/min/m^2, Corrected for Body Water)

Experimental Regimen		Pre	Exp I	Exp II	Rec
ST O	U	152.0	134.5	136.5	167.2
	L	176.5	134.2	145.2	169.8
0/100/0	U	168.0	134.0	124.5	159.5
1000	L	163.5	132.5	118.0	172.0
0/100/0	U	153.5	135.5	128.0	163.5
2000	L	147.0	129.0	129.0	147.5
2/20/78	U	156.0	109.0	136.0	165.0
1000	L	195.0	136.0	130.0	195.0
2/20/78	U	170.0	151.0	138.0	181.0
2000	L	162.0	131.0	128.0	136.0
15/52/33	U	179.0	139.5	141.5	172.0
1000	L	161.0	136.5	130.5	173.5
15/52/33	U	157.0	151.0	132.0	-----
2000	L	143.0	146.5	136.0	168.0
15/52/33	U	167.8	154.8	156.8	159.5
3000	L	154.5	155.0	153.0	169.3
30/0/70	U	156.0	136.0	125.0	168.0
1000	L	156.0	143.0	138.0	180.0
30/0/70	U	165.0	120.0	170.0	180.0
2000	L	160.0	160.0	170.0	179.0

TABLE III. 84

NUTRIENT REGIMEN VS. RESTING CORRECTED OXYGEN CONSUMPTION: 1953

(Corrected for Body Water)

Periods	O_2 Consumption ml/min/m^2 Normal Mixtures	Abnormal Mixtures
PU	169	158
PL	154	167
P	161	162
EIU	150	133
EIL	148	136
EI	149	134
EIIU	149	136
EIIL	143	137
EII	148	136
EU	149	134
EL	146	136
E	147	135

TABLE III. 84 (Contd)

B. STATISTICAL ANALYSES

Normal Mixtures			Abnormal Mixtures		
Test	X^2	P	Test	X^2	P
P vs. EI	4.46	c.0.03	P vs. EI	16.74	<0.01
P vs. EII	2.30	n.s.	P vs. EII	16.74	<0.01

TABLE III. 85

MEAN RESTING PULMONARY VENTILATION: 1953

(l/min/m^2, Corrected for Body Water)

Experimental Regimen		Pre	Exp		Rec
ST 0	U	3.20	3.02	2.76	3.57
	L	4.79	3.67	3.57	3.62
0/100/0	U	4.02	3.27	2.90	3.41
1000	L	3.27	2.70	2.47	3.58
0/100/0	U	3.42	2.84	2.88	3.66
2000	L	3.86	3.14	2.84	3.74
2/20/78	U	3.08	1.71	2.88	3.43
1000	L	5.80	2.91	2.99	4.84
2/20/78	U	3.66	3.41	2.69	4.20
2000	L	3.50	2.76	2.60	2.96
15/52/33	U	3.80	2.95	3.30	3.82
1000	L	3.14	2.55	2.51	3.50
15/52/33	U	3.94	3.48	3.54	3.32
2000	L	3.56	3.28	3.40	3.54
15/52/33	U	3.65	3.81	3.56	3.36
3000	L	3.30	3.97	3.19	3.80
30/0/70	U	3.17	2.97	2.31	3.78
1000	L	3.32	3.32	2.94	3.82
30/0/70	U	3.78	2.91	3.23	4.09
2000	L	3.27	3.16	2.51	3.26

FIGURE III. 33. RESTING CARBON DIOXIDE PRODUCTION (1953) VS. TOTAL CALORIES, AND PER CENT PROTEIN (P), CARBOHYDRATE (CHO), AND FAT.

TABLE III. 86

NUTRIENT REGIMEN VS. RESTING PULMONARY VENTILATION: 1953
(Corrected for Body Water)

A. SUMMARY OF MEANS

Periods	Pulmonary Ventilation $l/min/m^2$ Normal Mixtures	Abnormal Mixtures
PU	3.76	3.44
PL	3.32	4.11
P	3.54	3.78
EIU	3.51	2.94
EIL	3.44	3.22
EI	3.48	3.08
EIIU	3.45	2.80
EIIL	3.06	3.01
EII	3.27	2.91
EU	3.50	2.88
EL	3.25	3.12
E	3.38	3.00

B. STATISTICAL ANALYSES

Normal Mixtures			Abnormal Mixtures		
Test	X^2	P	Test	X^2	P
PU vs. PL	0.00	n.s.	PU vs. PL	3.60	c.0.050
EI vs. EII	0.08	n.s.	P vs. EI	8.47	0.015
EU vs. EL	0.98	n.s.	P vs. EII	14.43	< 0.01
P vs. E	5.00	c.0.025	EIIU vs. EIIL	2.02	n.s.

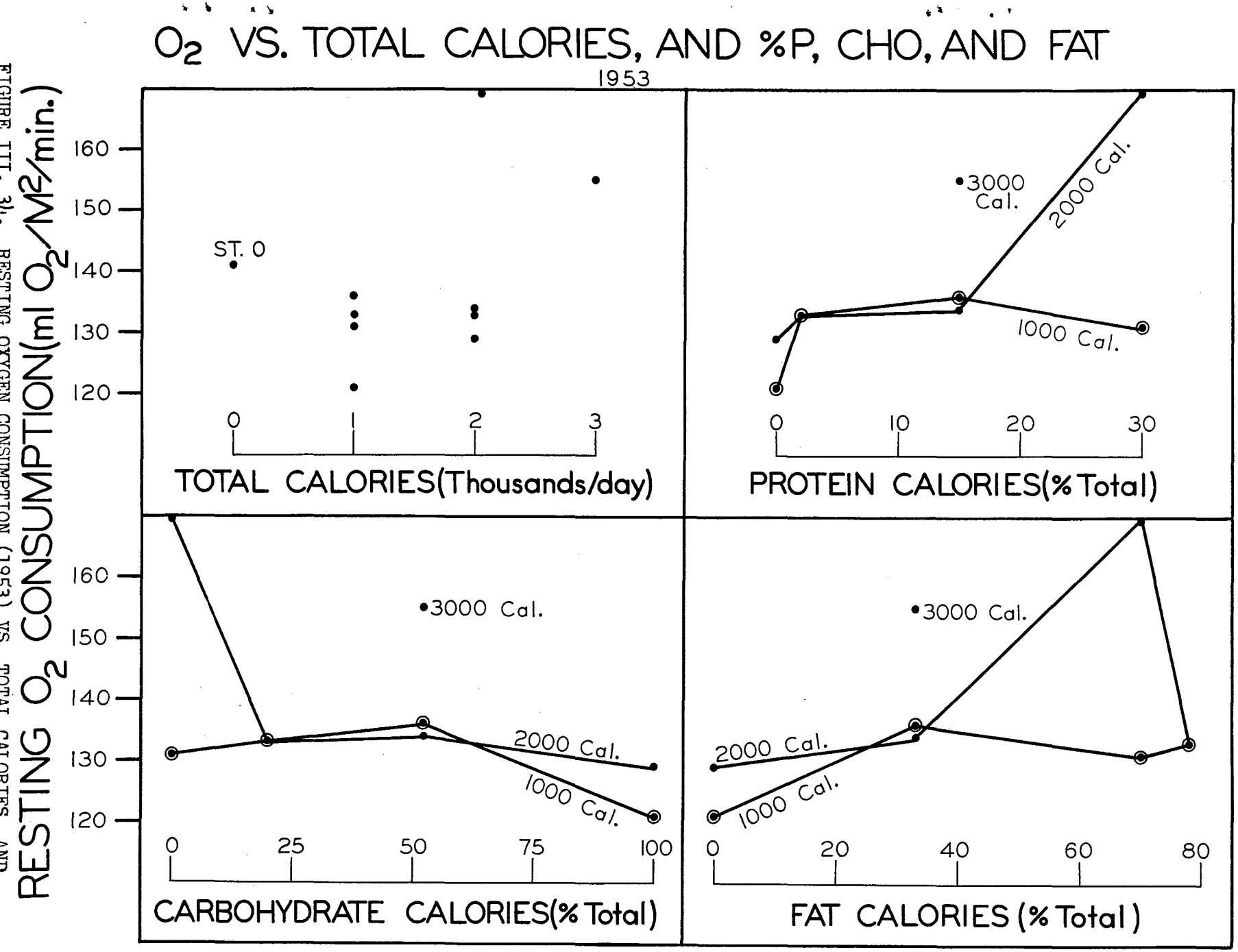


FIGURE III. 34. RESTING OXYGEN CONSUMPTION (1953) VS. TOTAL CALORIES, AND PER CENT PROTEIN (P), CARBOHYDRATE (CHO), AND FAT

TABLE III. 87

MEAN RESTING CARBON DIOXIDE PRODUCTION: 1954

(ml/min/m^2, Corrected for Body Water)

Experimental Regimen		Hard Work		Light Work	
		Pre	Exp	Pre	Exp
ST 0	U	97	84	131	89
	L	112	47	137	46
0/100/0	U	115	90	123	129
1000	L	117	90	140	51
0/100/0	U	103	127	123	116
2000	L	121	75	178	85
2/20/78	U	126	98	130	86
1000	L	96	75	159	74
2/20/78	U	156	110	130	107
2000	L	137	96	155	57
15/52/33	U	146	139	142	113
1000	L	62	95	90	52
15/52/33	U	126	116	130	100
2000	L	84	104	---	54
15/52/33	U	134	114	120	109
3000	L	99	122	---	95
30/0/70	U	110	117	131	117
1000	L	131	105	160	70
30/0/70	U	131	102	131	116
2000	L	81	94	153	73

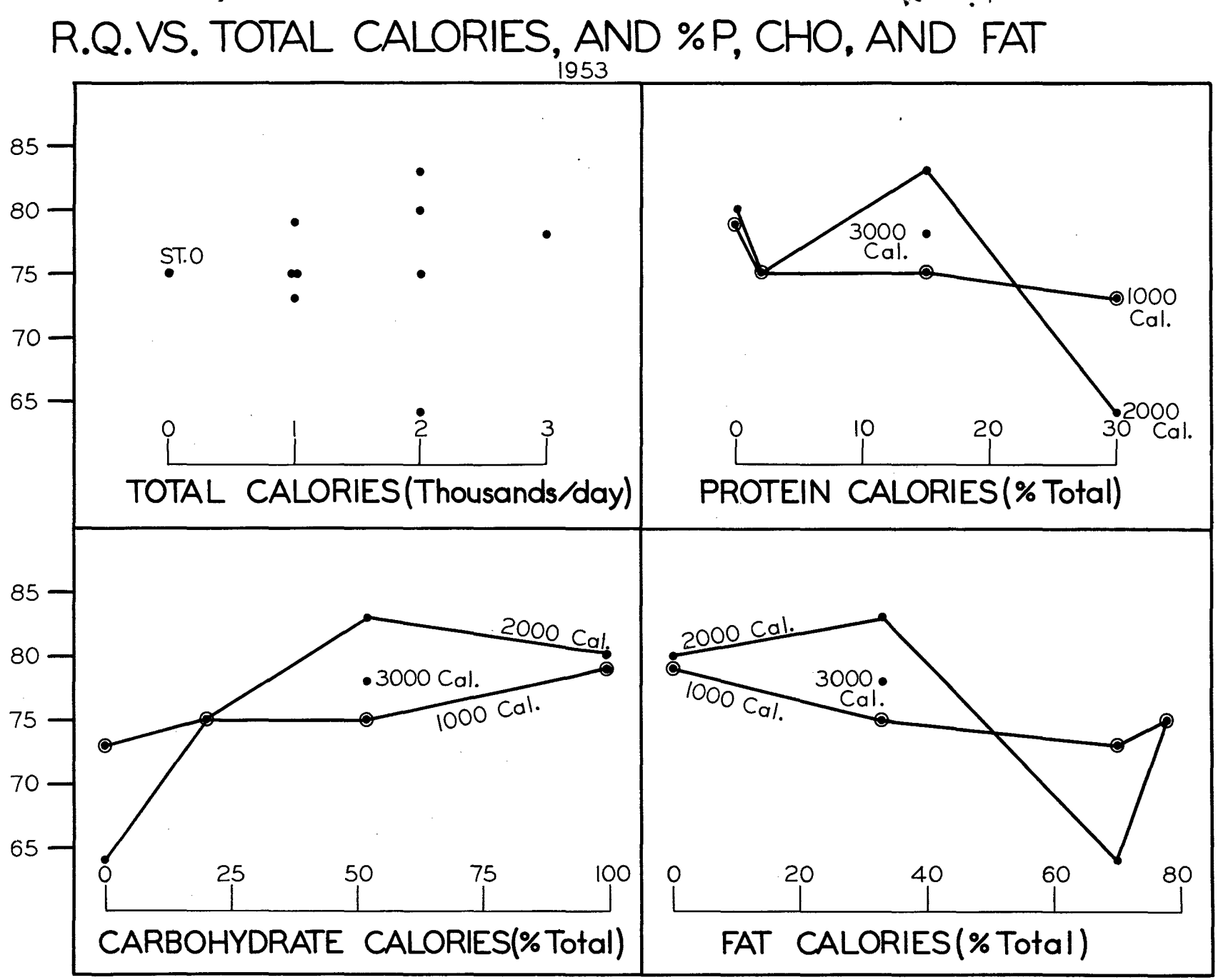


FIGURE III. 35. RESTING RESPIRATORY QUOTIENT (R.Q., 1953) VS. TOTAL CALORIES, AND PER CENT PROTEIN (P), CARBOHYDRATE (CHO), AND FAT.
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TABLE III. 88

NUTRIENT REGIMEN VS. RESTING CARBON DIOXIDE PRODUCTION: 1954
(Corrected for Body Water)

A. SUMMARY OF MEANS

	CO_2 Production, ml/min/m^2			
	Hard Work		Light Work	
Periods	Normal Mixtures	Abnormal Mixtures	Normal Mixtures	Abnormal Mixtures
PU	135	117	131	122
PL	81	112	90	153
P	111	114	121	141
EIIU	123	104	107	113
EIIL	108	90	67	65
EII	116	97	87	89

B. STATISTICAL ANALYSES: U

Normal Mixtures			Abnormal Mixtures		
Test	X^2	P	Test	X^2	P
PH vs. EIIH	5.50	c.0.02	PH vs. EIIH	8.04	< 0.01
PS vs. EIIS	9.38	< 0.01	PS vs. EIIS	4.83	c.0.04
EIIH vs. EIIS	----	----	EIIH vs. EIIS	----	----
PHS vs. EIIHS	11.38	< 0.01	PHS vs. EIIHS	8.04	c.0.07

TABLE III. 89

MEAN RESTING OXYGEN CONSUMPTION: 1954

($ml/min/m^2$, Corrected for Body Water)

Experimental Regimen		Hard Work Pre	Hard Work Exp	Light Work Pre	Light Work Exp
ST 0	U	134	120	145	144
	L	130	82	120	75
0/100/0	U	141	128	133	104
1000	L	186	74	124	74
0/100/0	U	127	111	147	104
2000	L	166	118	131	66
2/20/78	U	137	124	126	128
1000	L	126	100	143	80
2/20/78	U	143	138	142	124
2000	L	181	118	126	96
15/52/33	U	177	152	168	122
1000	L	96	108	102	89
15/52/33	U	156	140	128	97
2000	L	110	104	---	88
15/52/33	U	155	132	138	133
3000	L	146	150	---	80
30/0/70	U	123	144	138	130
1000	L	180	99	140	77
30/0/70	U	121	141	114	150
2000	L	120	136	139	85

TABLE III. 90

NUTRIENT REGIMEN VS. RESTING OXYGEN CONSUMPTION: 1954

(Corrected for Body Water)

A. SUMMARY OF MEANS

	O_2 Consumption, $ml/min/m^2$			
	Hard Work		Light Work	
Periods	Normal Mixtures	Abnormal Mixtures	Normal Mixtures	Abnormal Mixtures
PU	163	132	144	136
PL	119	152	102	131
P	143	142	134	133
EIIU	142	129	118	126
EIIL	124	105	86	80
EII	134	118	102	106

TABLE III. 90 (Contd)

B. STATISTICAL ANALYSES: U

Normal Mixtures			Abnormal Mixtures		
Test	X^2	P	Test	X^2	P
PH vs. EIIH	5.49	<0.02	PH vs. EIIH	n.s.	n.s.
PS vs. EIIS	7.12	<0.01	PS vs. EIIS	n.s.	n.s.
PH vs. PS	n.s.	n.s.	---	--	--
EIIH vs. EIIS	n.s.	n.s.	---	--	--
PRS vs. EIIHS	9.19	0.01	---	--	--

TABLE III. 91

MEAN RESTING PULMONARY VENTILATION: 1954

($l/min/m^2$, Corrected for Body Water)

Experimental Regimen		Hard Work		Light Work	
		Pre	Exp	Pre	Exp
ST 0	U	3.44	2.79	3.80	2.64
	L	4.64	2.79	4.53	2.63
0/100/0	U	3.75	3.27	3.82	3.22
1000	L	4.28	3.18	4.22	2.50
0/100/0	U	3.24	3.23	3.49	2.86
2000	L	5.05	3.44	4.80	3.17
2/20/78	U	4.00	3.38	3.93	3.29
1000	L	4.02	2.76	4.61	3.10
2/20/78	U	4.02	3.14	3.96	3.32
2000	L	3.25	2.74	4.60	4.06
15/52/33	U	4.92	3.64	4.18	3.42
1000	L	4.45	2.98	3.84	2.69
15/52/33	U	4.08	3.39	4.46	3.60
2000	L	3.40	3.00	4.94	3.74
15/52/33	U	3.78	3.24	3.87	3.11
3000	L	4.52	3.60	5.02	4.50
30/0/70	U	3.12	3.14	3.66	3.24
1000	L	4.44	2.84	4.55	2.98
30/0/70	U	3.76	2.96	4.62	3.82
2000	L	5.20	2.84	5.22	3.12

TABLE III. 92

NUTRIENT REGIMEN VS. RESTING PULMONARY VENTILATION: 1954
(Corrected for Body Water)

A. SUMMARY OF MEANS

	Pulmonary Ventilation, l/min/m^2			
	Hard Work		Light Work	
Period	Normal Mixtures	Abnormal Mixtures	Normal Mixtures	Abnormal Mixtures
PU	4.26	3.60	4.17	3.89
PL	4.27	4.51	4.60	4.64
P	4.26	4.02	4.38	4.26
EIIU	3.42	3.13	3.37	3.20
EIIL	3.23	2.93	3.64	3.08
E	3.33	3.02	3.51	3.14

B. STATISTICAL ANALYSES

Normal Mixtures			Abnormal Mixtures		
Test	X^2	P	Test	X^2	P
PHSUL vs. EIIHSUL	7.39	< 0.01	PUH vs. PLH	6.94	< 0.01
			PUS vs. PLS	1.25	n.s.
			PUHS vs. EIIUHS	--	< 0.01
			PLHS vs. EIILHS	--	< 0.01

4. Cardiovascular Function

Pulse Rate. The mean values for the pulse rate for Flights 1, 2, 3, and 4 for the control subjects have been tabulated for the first and second weeks of the pre-period (Table III. 93). The values are within the accepted range of normal and the inter-individual variability is of the order of eight per cent. There is no significant difference in the mean pulse rates when weeks 1 and 2 are compared.

Control subjects: During the six-week period of the investigation the pulse rates did not vary significantly in the case of either the flight leaders of the hard work groups or the light work groups (Table III. 94).

Experimental subjects: The experimental regimens provoked marked variations in the pulse rate. These variations are summarized in Table III. 94.

Nutrient mixture: It is a well known fact that diets deficient in calories produce a slowing of the pulse rate. The fact has been amply confirmed by the results of this investigation. The most notable decreases in the heart rate were observed in subjects subsisting on starvation and 1000-Calorie regimens. Several 2000-Calorie regimens also caused a decrease. These were: (1) 0/100/0 and 2/20/78 for both water regimens and work loads and (2) 15/52/33 and 30/0/70 for limited water and hard work. A decrease also occurred in the second week on the regimen of 15/52/33 3000 L.

Intake of water and osmotically active material: More significant in influencing pulse rate than caloric level and distribution of calories were water and osmotically active materials. Materials contributing to potential osmotic load are minerals and nitrogen. Their intake was relatively low by men subsisting on 0/100/0 and 2/20/78 and relatively high by men on 15/52/33 and 30/0/70. Examination of Table III. 94 suggests that the pulse rate decreased as much among subjects on unlimited water as among those on limited water in the case of men subsisting on diets low in osmotically active material (ST 0, 0/100/0, and 2/20/78). In the case of the high osmotic loads (15/52/33 and 30/0/70) the men on limited water showed a marked bradycardia even when the caloric intake was 3000 Cal/day. This effect of water, however, was evident only among men doing hard work.

Water, work, and osmotic load then seemed to influence the bradycardia. A study was made of these factors. The data used were those collected during EXP II (Table III. 95). It will be recalled that in the pre-period there were no significant differences in pulse rates among the four groups of experimental subjects. In EXP II, marked differences appeared: the men of Flight 2 (hard work, limited water) had a mean pulse rate of 48. This bradycardia was significantly different from that of Flight 1 (hard work, unlimited water) by the Chi-Square test. On the other hand, water had no influence on the bradycardia among men performing light work. When the effect of intake of osmotically active materials was separated, it was evident that for three regimens (hard work, unlimited water, and light work limited and unlimited water) the reduction in pulse rate from pre-period was confined to those subjects subsisting on diets supplying low amounts of potentially osmotic substance. When the work was hard, the water deficit was the primary cause of the bradycardia. Caution must be exercised in attaching physiological significance to these differences at this stage of our analysis, but the finding emphasizes the need for an especially careful scrutiny of mineral metabolism and the formulation of a precise definition of osmotic potential of any given regimen.

Recovery period: One of the interesting findings of the investigation was the frequency with which pulse rates in excess of 80 beats/min occurred during the second week of the recovery period. Whereas no mean exceeded 78 in the pre-period, a mean of 80 was recorded 12 times in REC II for experimental subjects and once for controls. This increased rate may have been related to the change to garrison ration from the packaged 5-in-1 ration.

Blood Pressure. The mean pre-period values for the systolic and diastolic blood pressure are given in Table III. 93. The values are those that would be expected for the age groups involved and the inter-individual variability was of the order of 5 to 10%. The two series of means (P I and P II) are not significantly different.

Control subjects: The mean values for systolic blood pressure (Table III. 96) and for diastolic blood pressure (Table III. 97) during the three phases of the investigation did not vary appreciably.

Experimental subjects: There were no significant changes in either the systolic blood pressure (Table III. 96) or the diastolic blood pressure

(Table III. 97) during the course of the investigation, including recovery. Furthermore there was no evident effect of water intake or work load on the mean blood pressure.

TABLE III. 93

PRE PERIOD DATA ON RESTING PULSE RATE AND BLOOD PRESSURE

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
			Pulse Rate, beats/min			
Flight 1	70	6.2	8.9	66	9.3	14.1
Flight 2	68	8.4	12.3	65	7.0	10.8
Flight 3	69	7.5	10.9	67	7.8	11.6
Flight 4	68	7.8	11.4	68	8.0	11.8
Controls	72	8.4	11.7	71	9.3	13.1
			Systolic Blood Pressure, mm Hg			
Flight 1	115	8.2	7.1	119	3.8	3.2
Flight 2	111	11.3	10.2	120	8.7	7.3
Flight 3	116	7.4	6.4	119	3.2	2.7
Flight 4	120	6.7	5.6	122	3.6	2.9
Controls	122	7.1	5.9	122	3.7	3.0
			Diastolic Blood Pressure, mm Hg			
Flight 1	76	5.8	7.6	76	8.7	11.5
Flight 2	72	9.4	13.0	73	3.7	5.1
Flight 3	74	8.2	11.1	73	4.6	6.3
Flight 4	79	8.1	10.2	74	6.6	8.9
Controls	81	5.4	6.6	80	7.3	9.2

TABLE III. 94

RESTING PULSE RATE
(beats/min)

Experimental Regimen		Hard Work Pre*	Exp I	Exp II	Rec I	Rec II	Light Work Pre*	Exp I	Exp II	Rec I	Rec II
ST 0	U	66	49	46	65	80	70	52	52	61	83
	L	70	56	50	73	82	63	56	47	60	68
0/100/0	U	78	52	48	60	84	68	56	54	64	76
1000	L	72	56	48	60	76	72	56	46	56	60
0/100/0	U	71	48	44	48	72	79	64	60	76	80
2000	L	70	56	46	56	66	70	58	58	66	66
2/20/78	U	73	58	48	66	88	71	67	60	70	92
1000	L	61	48	48	66	70	68	54	56	60	72
2/20/78	U	70	52	52	60	76	65	53	52	69	72
2000	L	61	50	48	57	66	69	54	46	60	60
15/52/33	U	64	42	40	56	64	62	48	44	66	72
1000	L	68	60	50	74	62	73	68	60	70	72
15/52/33	U	66	66	72	60	74	61	62	66	56	60
2000	L	64	64	48	66	72	66	62	66	72	66
15/52/33	U	75	70	64	60	72	66	70	66	64	82
3000	L	67	62	50	60	62	70	70	66	72	72
30/0/70	U	62	64	60	66	82	67	66	58	86	78
1000	L	63	60	48	60	80	63	58	50	68	76
30/0/70	U	63	64	70	56	82	70	68	62	78	84
2000	L	65	52	48	58	66	67	80	74	62	66
Control	U	71	72	65	63	75	74	76	75	73	81
	L	70	77	71	71	72	71	76	68	71	66

*Mean values for PI and PII.

TABLE III. 95

EFFECT OF INTAKE OF WATER AND OSMOTICALIY ACTIVE SUBSTANCES ON RESTING PULSE RATE IN EXP II*

Relative Osmotically Active Intake	Hard Work Water U	Hard Work Water L	Light Work Water U	Light Work Water L
Low	52	48	56	52
High	66	48	63	64
Mean	57(1)	48(1)	58(2)	58(2)

*Subjects on ST 0 and 15/52/33 1000 not included.

(1) Difference significant by Chi-Square Test: $X^2 = 17.50$; $P < 0.01$

(2) Difference not significant by Chi-Square Test: $X^2 = 0.78$

TABLE III. 96

RESTING SYSTOLIC BLOOD PRESSURE
(mm Hg)

Experimental Regimen		Hard Work					Light Work				
		Pre*	Exp		Rec		Pre*	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	117	112	105	116	112	120	116	118	118	120
	L	116	120	116	115	120	122	120	121	113	117
0/100/0	U	116	120	121	110	120	118	118	115	115	114
1000	L	122	116	119	120	114	126	123	115	125	117
0/100/0	U	119	120	114	120	124	122	120	120	115	120
2000	L	115	118	118	120	118	119	124	117	122	110
2/20/78	U	118	125	116	125	116	117	122	109	119	119
1000	L	108	119	114	119	120	120	122	113	110	115
2/20/78	U	109	124	110	112	100	113	118	115	122	123
2000	L	117	124	121	111	119	120	124	115	122	118
15/52/33	U	111	116	118	117	120	114	114	120	120	120
1000	L	118	116	115	120	119	122	130	117	120	120
15/52/33	U	120	123	124	122	115	116	119	120	118	116
2000	L	119	119	115	120	123	120	119	122	108	109
15/52/33	U	118	118	115	115	110	116	119	114	119	127
3000	I	118	121	110	120	120	119	119	115	115	115
30/0/70	U	118	118	115	120	125	120	120	119	119	119
1000	L	110	120	115	122	119	118	118	111	120	115
30/0/70	U	123	120	124	114	119	116	122	104	119	114
2000	L	108	119	115	115	110	122	119	117	118	105
Control	U	127	120	117	123	119	120	119	113	126	118
	L	120	118	113	122	120	122	121	115	116	125

*Mean values for PI and PII.

TABLE III. 97

RESTING DIASTOLIC BLOOD PRESSURE
(mm Hg)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	77	72	72	77	72	76	72	78	73	71
	L	76	77	76	76	74	81	77	84	79	76
0/100/0	U	75	73	74	79	74	68	72	72	75	74
1000	L	71	74	73	78	71	73	80	74	84	75
0/100/0	U	80	70	78	78	72	76	75	78	74	79
2000	L	70	70	74	79	75	79	80	74	80	70
2/20/78	U	79	84	70	89	80	76	75	74	74	75
1000	L	64	73	74	79	79	78	79	78	80	70
2/20/78	U	72	78	68	80	70	75	73	70	79	75
2000	L	77	78	78	74	79	73	75	81	79	83
15/52/33	U	69	73	78	79	70	72	73	78	74	72
1000	L	78	74	78	74	74	75	84	78	75	75
15/52/33	U	82	76	74	78	74	71	78	78	79	74
2000	L	77	77	78	75	75	79	70	78	75	78
15/52/33	U	77	70	70	75	75	70	74	68	79	70
3000	L	74	79	70	78	74	74	74	78	77	75
30/0/70	U	74	73	74	82	74	77	78	78	74	74
1000	L	66	79	78	75	80	72	75	76	75	75
30/0/70	U	78	78	74	70	75	74	74	78	74	75
2000	L	66	69	78	79	70	80	75	79	79	75
Control	U	85	75	78	78	76	77	75	78	73	76
	L	80	73	73	79	79	81	75	76	73	73

*Mean values for PI and PII.

5. Central Nervous System

Passage of Time. All subjects judged the passage of time against a stop watch. The intervals were estimated: 20, 45, and 70 seconds, and the conditions of testing were closely comparable to those employed on the student-group in 1953. In the pre-periods, the volunteer subjects tend to underestimate the intervals of time and their estimates were generally shorter than those of the ration controls (Table III. 98). The estimates of these airmen, furthermore, tended to be shorter than those of the 1953 group of students. Since the airmen were relatively young men (mean age, 18 years), the question certainly can be raised that the estimate of the passage of time is a function of age.

It is commonly recognized that time passes more rapidly as one grows older. If psychological time passes slowly, one would tend to underestimate the passage of horologic time; if one judges time to pass rapidly, he would overestimate horologic time. Our accumulated data (Table III. 99) were examined for evidences of such a trend and in a general way the results confirmed the naturalistic observation. At the 20-second level, there was no

apparent influence of age. At the 45- and 70-second levels there was a strikingly close relation between the sense of time and age. For the student-group there was almost a linear increase between 20 and 26 years in the case of the 45-second interval. The observations on the ration controls, whose ages ranged from 21 to 41 years, suggest that after about 25-30 the positive correlation breaks down; i.e., age no longer seems to influence the sense of time. Because of the wide inter- and intra-individual variability of this measurement, we hesitate to make more than general remarks regarding this correlation. The evidence is intriguing! Perhaps the accumulation of a larger body of data would support more strongly the impression so many have about the flight of time.

Turning to the time measurements for the six weeks of the study, we find that the stresses of work, exertion, water intake, and nutrient intake produced no consistent trends (Tables III. 100, 101, and 102). In a number of instances there were large increases or decreases in the estimates in either EXP II or REC I. Such changes in either direction were not sufficiently regular to warrant any generalizations.

In so far as the evidence obtained here is applicable to metabolic problems, interpretation according to the concepts of Hoagland (1935) leads to the conclusion that metabolic turnover in general is more rapid in younger men than in older men.

TABLE III. 98

PRE-PERIOD DATA ON PASSAGE OF TIME
(20, 45, and 70 seconds)

Groups of Subjects	P I M	P I Range	P II M	P II Range
		20 seconds		
Flight 1	17.6	6.2-32.8	19.7	8.5-40.8
Flight 2	14.1	3.5-26.3	13.9	5.0-30.0
Flight 3	19.1	4.6-38.0	20.5	12.0-37.7
Flight 4	16.4	5.5-43.0	17.6	5.7-35.3
Controls	19.9	10.4-30.5	20.9	16.5-31.5
		45 seconds		
Flight 1	40.7	17.7-57.0	45.9	12.7-83.3
Flight 2	32.8	11.9-66.0	35.8	11.6-59.4
Flight 3	39.1	10.3-63.4	39.3	21.5-69.4
Flight 4	33.4	9.1-69.6	35.6	11.6-59.1
Controls	42.6	22.2-62.0	45.3	36.4-66.6
		70 seconds		
Flight 1	73.4	30.0-99.0	69.6	41.0-124.5
Flight 2	59.2	20.0-120.5	51.0	18.1-92.4
Flight 3	61.1	24.7-92.2	64.5	35.7-110.2
Flight 4	54.8	13.1-103.0	52.0	20.8-99.0
Controls	71.5	34.4-95.6	72.7	54.5-96.7

TABLE III. 99

PASSAGE OF TIME VS. AGE
(Mean Pre-period Values)

Subjects	Age Yr.	Estimate of Passage of Time 20 sec.	45 sec.	70 sec.
Flight 1	18	18.6	43.3	71.5
Flight 2	18	14.0	34.3	55.1
Flight 3	18	19.8	39.2	62.8
Flight 4	18	17.0	34.5	53.4
No. 6	20	19.3	44.0	64.4
No. 1	21	23.7	46.2	76.8
No. 5	22	20.8	49.0	76.4
No. 8	22	21.7	51.9	81.9
No. 2	23	20.2	48.2	77.0
No. 12	24	22.0	51.5	79.6
No. 3	25	20.6	54.6	82.8
No. 9	25	19.9	53.7	77.0
No. 7	26	23.6	57.8	82.0
Controls	28	20.4	44.0	72.1

TABLE III. 100
PASSAGE OF TIME: 20 SECONDS

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	20.2	23.1	23.9	32.4	32.2	19.4	13.0	26.9	20.6	28.2	22.1	27.8
	L	17.4	11.4	11.1	12.2	14.0	17.0	15.5	15.3	17.1	22.5	16.8	15.0
0/100/0	U	19.0	17.8	19.6	21.6	21.7	23.6	15.2	12.9	10.6	11.6	12.1	23.4
1000	L	13.5	22.0	17.8	17.2	18.0	18.6	22.4	26.5	26.1	20.4	40.8	16.8
0/100/0	U	13.6	23.6	18.6	30.3	20.0	24.1	13.2	14.6	18.0	17.6	19.4	19.8
2000	L	16.0	17.0	17.4	18.3	17.2	18.7	13.5	21.2	15.0	17.8	12.8	15.2
2/20/78	U	11.0	17.6	21.8	23.6	28.8	18.6	16.8	19.2	18.3	16.8	16.9	17.4
1000	L	9.9	11.9	11.9	15.1	17.2	13.6	18.8	16.6	14.8	15.6	19.5	16.8
2/20/78	U	26.6	22.6	25.6	24.2	22.2	29.4	29.2	26.0	22.5	17.4	21.2	31.5
2000	L	11.7	13.4	16.5	14.8	24.0	18.1	9.0	23.8	22.0	18.7	34.5	26.6
15/52/33	U	11.7	10.6	12.8	12.0	19.6	19.0	22.0	17.8	17.9	17.1	20.8	14.5
1000	L	6.4	11.3	11.2	27.2	23.9	17.9	25.8	17.2	23.9	23.0	26.1	25.8
15/52/33	U	9.8	16.4	17.8	15.1	20.7	32.7	25.0	29.8	24.2	21.0	16.2	17.6
2000	L	14.4	9.7	21.8	26.6	23.4	18.4	6.4	19.2	18.2	13.6	13.1	14.6
15/52/33	U	21.5	19.0	20.1	20.8	21.2	18.2	16.2	12.8	16.7	18.0	15.0	15.0
3000	L	21.7	17.4	19.6	20.7	22.6	15.0	31.3	13.4	14.4	12.7	9.7	16.0
30/0/70	U	18.4	24.9	20.6	17.2	20.4	21.2	18.0	22.6	19.0	25.2	25.0	17.6
1000	L	15.6	12.6	15.6	19.7	14.0	17.0	8.8	16.0	11.1	16.8	6.6	8.3
30/0/70	U	18.0	18.4	20.1	18.8	18.4	19.0	24.3	18.6	14.0	16.4	15.8	16.0
2000	L	11.2	11.3	19.7	13.8	21.0	9.8	13.2	12.4	8.5	11.0	11.3	15.0
Control	U	19.5	18.7	17.4	17.7	18.6	20.4	21.6	20.1	21.8	16.2	25.5	19.7
	L	21.1	23.9	20.8	18.8	20.8	20.9	17.4	20.7	22.3	19.9	24.4	21.4

TABLE III. 101
PASSAGE OF TIME: 45 SECONDS

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST O	U	42.6	49.1	57.7	72.4	55.8	38.9	25.4	45.2	52.0	40.8	42.2	38.9
	L	40.4	22.8	24.0	35.9	29.9	40.1	36.7	38.1	36.2	36.1	36.3	32.8
0/100/0	U	54.1	40.5	59.4	42.9	55.8	52.3	23.0	22.6	25.2	25.0	29.8	33.4
1000	L	31.9	46.4	40.0	33.0	32.6	40.1	46.4	47.6	46.0	32.7	33.9	30.6
0/100/0	U	44.8	44.2	35.5	62.2	56.4	50.4	29.4	32.4	38.4	41.1	43.0	45.7
2000	L	36.0	33.0	46.8	32.2	40.5	48.3	28.0	38.1	19.8	28.5	29.2	26.5
2/20/78	U	37.8	44.7	44.0	51.4	62.1	44.2	39.6	30.4	39.8	36.8	45.8	37.8
1000	L	14.9	54.7	38.6	44.6	49.2	39.6	36.4	26.0	27.0	28.8	37.7	36.6
2/20/78	U	48.4	66.5	50.5	39.0	53.7	51.5	54.3	58.5	48.1	37.0	32.5	58.9
2000	L	22.7	27.3	34.6	37.5	45.5	45.1	38.5	30.6	61.6	38.4	41.4	53.2
15/52/33	U	25.3	23.6	33.3	37.3	40.3	43.2	49.0	41.3	53.6	36.0	49.0	49.0
1000	L	32.2	42.2	34.5	33.0	41.8	42.4	43.4	35.8	44.3	43.0	44.0	40.8
15/52/33	U	23.4	56.5	35.0	32.2	43.9	32.7	43.0	56.8	50.0	54.4	33.6	39.5
2000	L	25.9	23.5	52.0	48.0	49.2	38.4	23.6	45.3	38.2	40.7	36.3	47.0
15/52/33	U	45.8	41.7	52.5	40.8	41.8	40.3	30.7	25.4	40.9	39.9	33.8	35.4
3000	L	38.8	58.5	38.2	39.0	48.2	51.1	41.5	40.0	18.0	43.8	21.5	25.0
30/0/70	U	41.4	54.8	47.6	44.3	42.6	39.6	43.1	43.4	46.6	46.3	36.4	35.9
1000	L	48.7	26.6	33.5	43.6	39.4	36.2	18.1	28.6	29.4	42.4	18.6	29.9
30/0/70	U	33.0	33.6	31.8	28.2	46.0	45.2	52.5	34.2	44.0	25.1	30.4	42.4
2000	L	28.4	29.4	42.7	36.1	31.8	23.1	24.2	24.8	16.4	23.1	22.9	24.4
Control	U	38.7	40.1	40.8	41.0	47.1	48.3	50.4	36.8	50.8	46.3	52.7	44.7
	L	38.7	50.5	50.8	44.7	44.7	45.1	42.3	44.2	51.8	40.0	46.5	49.9

TABLE III. 102
PASSAGE OF TIME: 70 SECONDS

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	84.2	82.0	77.3	127.6	76.0	71.8	47.1	74.6	70.7	78.9	61.5	57.5
	L	67.7	28.4	45.4	51.7	67.8	51.8	53.2	44.3	54.3	48.2	63.0	40.9
0/100/0	U	83.0	77.1	61.4	50.0	85.8	74.5	53.7	36.0	36.5	55.8	56.4	61.1
1000	L	53.2	59.6	53.9	59.6	59.0	63.5	70.6	77.4	67.2	55.8	52.8	53.5
0/100/0	U	66.4	72.3	52.2	93.8	89.5	64.5	50.4	51.0	59.6	58.7	66.9	68.6
2000	L	82.0	62.2	57.6	74.0	60.2	64.6	33.4	69.1	45.5	42.7	42.4	36.0
2/20/78	U	87.2	65.4	69.6	80.0	105.8	57.5	66.4	57.6	67.5	65.9	70.8	77.9
1000	L	45.3	49.8	52.4	53.6	69.9	60.8	81.0	30.2	47.8	45.4	50.2	47.3
2/20/78	U	75.3	80.6	42.4	61.8	77.2	79.0	80.0	89.5	80.8	59.6	47.4	63.0
2000	L	42.2	55.0	58.8	53.1	63.4	75.2	43.8	62.0	70.8	73.1	56.0	92.9
15/52/33	U	58.5	50.0	61.6	68.2	76.9	72.9	72.6	69.3	64.1	65.0	63.0	66.3
1000	L	58.0	49.1	66.4	50.0	78.2	45.0	55.2	50.1	72.3	65.0	60.9	61.0
15/52/33	U	65.8	57.9	54.6	51.6	63.6	48.7	67.6	62.6	85.8	54.7	34.2	41.4
2000	L	38.8	32.7	65.0	68.9	60.8	57.3	45.9	57.6	52.5	53.0	61.4	58.8
15/52/33	U	68.5	69.1	67.5	75.4	52.4	60.2	54.6	49.2	51.8	57.0	41.8	47.0
3000	L	62.2	68.6	65.6	61.0	72.2	51.0	83.0	56.4	35.4	61.8	33.5	44.0
30/0/70	U	78.6	77.3	70.6	68.8	61.8	70.6	55.2	93.4	64.6	54.2	68.8	65.3
1000	L	91.4	55.5	40.9	71.3	61.6	52.1	39.2	44.7	53.7	61.4	39.4	66.6
30/0/70	U	52.3	51.8	45.1	61.0	70.6	61.4	72.8	57.0	62.3	47.0	47.2	61.6
2000	L	42.2	61.2	65.5	68.2	68.5	57.5	44.0	32.3	24.3	34.8	29.8	34.3
Control	U	62.5	78.7	68.2	69.1	74.9	75.9	77.9	67.9	73.4	73.7	85.1	67.1
	L	83.9	74.4	70.5	73.4	71.2	70.6	61.6	69.8	76.8	75.2	72.8	82.3

6. Hematology

Hematocrit. One of the simplest measures of shifts in the distribution of water within the body is the hematocrit. Although the measurement is easy to perform, the variations nevertheless only indicate gross shifts of water into or out of the blood cells. Moreover, the volume of water moved must be rather large to cause significant variations. Small changes in hydration may not evoke an alteration in the hematocrit.

The subjects of the present investigation had hematocrits which were well within the normal for the age groups involved (Table III. 103). There were no appreciable differences among the five groups and none when the first two weeks of the pre-period were compared.

Control subjects: During the six weeks of the study the mean weekly hematocrits for the four groups of control subjects revealed no consistent trends and the degree of variation was small (Table III. 104).

Experimental subjects: The mean weekly observations on the hematocrit are summarized in Table III. 104. Examination of these tables brings out two significant findings. First, in the experimental periods, the hematocrit generally deviated relatively little from the pre-period level. The limited water regimen did not cause a rise in the hematocrit. Work load had no appreciable effect. Second, the hematocrit fell markedly during the recovery period. The drop was most evident in REC I. This decrease was apparently independent of experimental nutrient mixture and water intake in the case of the hard work groups. On the other hand, among the light work groups, the fall was somewhat greater among those who had been on starvation and 1000 Cal/day than among those who had been on 2000 and 3000 Cal/day. Statistical examination of the change in hematocrit from the second pre-period to the two recovery weeks reveals that in all cases the decrease was highly significant (Table III. 105).

This marked alteration in the hematocrit suggests that during REC I a large volume of water was shifted into the blood. By REC II, some of this water had left the blood, for the hematocrits tended to return toward pre-period values. A similar phenomenon was observed in the temperate studies of 1953.

The questions naturally raised by this striking observation are (1) Was the diluting agent merely water or water containing salt? (2) From where did the water originate? (3) What caused the shift of fluids? Evidence has already been presented that there was a significant rise in the serum osmolarity (Table III. 32), serum sodium (Table III. 56), and serum chloride (Table III. 58) during the recovery periods. The fact that the hematocrit fell but the serum osmolarity rose signifies that the diluting fluid was saline. It is probable that extracellular water was mobilized because of the markedly increased salt intake during REC I. At the time of testing the subjects --- the day they began eating full diets and the day following --- these homeostatic adjustments were still in progress and an opportunity was presented to witness the magnitude of the response in full swing. In REC II, the elevation of the

serum electrolytes had largely disappeared and the hematocrit had began to return toward pre-period values, presumably as a result of redistribution of body fluids and increased renal output of extra water and salt.

Erythrocyte Sedimentation Rate. Two factors have made it difficult to analyze and interpret the data on the erythrocyte sedimentation rate: (1) high incidence of acute upper respiratory infections in the pre-periods and EXP I (Table III. 106A), and (2) highly variable room temperatures in the clinical laboratory. An acute respiratory infection may elevate the erythrocyte sedimentation rate (ESR). Accordingly, all observations were eliminated when (1) the subject had such an affliction and (2) the sedimentation rate exceeded 15 mm/hr. Furthermore, when the subject was given a dental extraction or was found to have such diseases as gingivitis or phimosis and balanitis, the sedimentation rates measured near the time of the illness were eliminated (Table III. 106B). All the data on two additional subjects were excluded: Subject No. 58 had chronic bronchial asthma and Subject No. 84 had a grade II systolic murmur and a persistently elevated ESR. It was thought that the latter individual, although there was no confirmatory history, might have had active rheumatic fever. Six other men had persistently elevated ESR's (Table III. 107). Since there was no rational basis for excluding measurements made on them, the values were included in the analyses.

It is well established that fluctuations in the temperature of the room in which the sedimentation rate is measured will alter the E.S.R.: elevation of the temperature will increase the E.S.R. and lowering of the temperature will decrease the E.S.R. (Nichols, 1942). Rather wide variations in room temperature occurred in the barracks used as the clinical laboratory (Table III. 108). The fact that even the mean temperature during the periods of measurement changed from time to time makes rigorous interpretation most difficult.

Pre-Period Data. The pre-period values for the E.S.R. for the five groups of subjects have been summarized in Table III. 109. These values are somewhat higher than those recorded during the temperate study and several exceed the normal range of 0-9 mm/hr cited by Albritton (1951). The highest values were measured for Flight 4 and this group included three of the six men who exhibited consistently elevated E.S.R.'s (Table III. 107: Nos. 76, 78, and 80). If these three men are excluded the pre-period means for this flight become 8 and 11, respectively. Two of the five groups show significant changes in the ESR when P I and P II are compared: Flight 1, a significant rise; and Flight 2, a significant fall.

Experimental Periods. In the temperate study of 1953 alterations in the nutrient intake were found to provoke significant elevations of the ESR. In general, the increase was most marked in EXP I; in EXP II the rate tended to return to pre-period values. This variation of the ESR has been confirmed in carefully controlled studies (Anderson, Meltzer, and Sargent, 1954) on additional young men. The altered ESR was found to be independent of the serum cholesterol and the concentration of such plasma proteins as fibrinogen and γ-globulin. Consequently, it was rather surprising to find that, in the present investigation, the several experimental nutrient combinations failed to cause

similar changes in the ESR (Table III. 110). Few of the variations measured were greater than those shown by the ration controls and no consistent pattern of response was evident. Among the suggestive variations confirming the work of 1953 are the marked increases in ESR for 30/0/70 1000 L hard work both in EXP I and EXP II. In general, interpretation of these data is greatly complicated by the wide variability of the temperature at which the rates were measured. In future tests of this sort, it is recommended that determination of the ESR be abandoned unless provision can be made for adequate standardization of room temperature. The ESR is a delicate measure of bodily response to stress and it would seem to be a worthwhile datum to include in all studies on the physiological aspects of survival rations.

Recovery Periods. The above comments apply equally both to experimental and recovery periods. No consistent reaction pattern is evident in the data of Table III. 110.

Leukocytes. From original data on the total white blood cell count and the differential, the absolute numbers of neutrophils, lymphocytes, monocytes, eosinophils, and basophils were calculated. The pre-period data for these several leukocytes have been brought together in Table III. 111. The means and ranges for each of the cells are well within range of normal values for mature man (Albritton, 1951). In addition there is the expected rather wide inter-individual and inter-group variability. One trend is evident. The total white blood cell, neutrophil, lymphocyte, and eosinophil counts all rise appreciably from P I to P II. The monocytes and basophils exhibit no such change. In some cases this trend was statistically significant as will be brought out in the paragraphs to follow.

Total white blood cell count: Examination of Table III. 112 fails to disclose any consistent correlations between changes in the white cell count and (1) work, (2) water intake, (3) calorie intake, and (4) distribution of calories between protein, carbohydrate, and fat. The principal finding was the tendency for the total count to fall in EXP I to low levels in EXP II and then rise again in the recovery periods. Since all groups, including the ration controls exhibited this alteration, it was thought to be a reaction to the total stress situation of the field phase.

A statistical study of the general trend was made (Table III. 113). Although the white count rose appreciably during the pre-periods, the trend was not statistically significant. The fall in the first experimental week was likewise not significant. However, by EXP II, the trend toward lowered white cell counts had reached significant proportions. The count rose again during recovery to levels similar to those observed during the pre-periods.

Neutrophil count: Changes in the neutrophils reflect closely the trends described for the total white blood cell count: work, water intake, caloric intake, and distribution of calories had no consistent effects (Table III. 114). Statistical analysis (Table III. 115) disclosed that again there was a significantly low neutrophil count in EXP II. The neutrophil count had returned to pre-period levels by REC II.

Lymphocyte count: The rise in the lymphocytes from P I to P II was significant at the 5% level by the X^2 test. The fall in the experimental periods, however, was largely independent of work, water, and nutrient combination (Table III. 116). Statistical analysis (Table III. 117) of the lymphopenic trend indicates that the drop was more rapid than in the case of the neutrophils; in EXP I the X^2 value was significant at the 2% level. The minimum values were reached in EXP II and then there followed a rise to pre-period levels in the two recovery weeks.

Basophil count: Examination of Table III. 118 reveals that the basophils, in contrast to the other leukocytes, tended to rise in EXP I and EXP II. This increase, however, seemed to be a general reaction to the field-complex rather than the result of a specific alteration of work, water, or diet. The mean values for the basophils during the six weeks were 21/mm^3 (for P I and II), 22, 32, 26, and 28 (Table III. 119A). The high of 32 was significantly greater than the pre-period value; during the recovery periods, the mean values were not significantly different from the pre-period levels (Table III. 119B). This rise during the field phase is reminiscent of the changes in the basophil count reported by investigators of the Medical Nutrition Laboratory (1948) for men abruptly exposed to the stress of extreme cold.

Eosinophil count: The absolute (calculated) eosinophil count, like the other leukocytes, did not show any variations which tended to discriminate among the several experimental conditions--work, water, and diet (Table III. 120). On the other hand there was a distinct trend toward low values in EXP II. Counts rose abruptly in REC I to levels tending to exceed the pre-period values. Analysis of this phasic variation (Table III. 121) indicated that during the six weeks of the investigation the mean counts were 254/mm^3 (P I and II), 210, 207, 329, 259. The minimum in EXP II was not significantly different from the pre-period mean whereas the maximum in REC II was significantly greater than the pre-period mean.

Monocyte count: The monocytes varied widely and failed to show either consistent changes with the experimental conditions or evidence of the general reaction described in the preceding paragraphs (Table III. 122). A similar finding has been reported by Sargent et al. (1954) for young men living under temperate conditions and engaging in moderate work.

Comment: Two patterns of response emerge from our observations on the leukocytes. First, the total white cell count, neutrophil count, lymphocyte count, and eosinophil count tended ro rise from P I to P II. In the case of the lymphocytes the rise was statistically significant at the 5% level. A fall in the numbers of these cells occurred in the first experimental week and reached minimum values in the second week. The drop in EXP I was significant only in the case of the lymphocytes. All cells except eosinophils exhibited a significant fall in EXP II. In the recovery period these counts returned to pre-period levels. This reaction pattern is graphically illustrated in the histograms of Figure III. 36. Second, the changes in the basophil count tended to be a mirror image of the first reaction pattern, and in EXP II there was a statistically significant increase in the basophils.

The first reaction pattern-leukopenic tendency-at the time of increased stress from environmental exposure, diet, and physical exertion is rather unexpected. Stress generally evokes a rise in leukocytes and neutrophils and a fall in lymphocytes and eosinophils. The pattern described is suggestive of the response to a virus infection and indeed a number of the personnel (subjects and staff) had a variety of upper respiratory symptoms and signs during the experimental weeks. Such a situation undoubtedly complicated the picture and makes a rigorous interpretation impossible.

Little is known regarding the functions of the basophil. Recently, however, evidence has been reported (Code, Mitchell, and Kennedy, 1954) that basophils like eosinophils decrease when healthy human subjects are given cortisone. In our subjects and in those studied by investigators at the Medical Nutrition Laboratory (1948), a complex of stresses including cold and undernutrition (which presumably evoked a greater output of such adrencortical hormones as cortisone) produced a rise in the basophils. Thus neither our observations nor those of the Army group exhibit the close parallelism between eosinophils and basophils reported by the workers at the Mayo Clinic (Code et al., 1954).

General Conclusions on Hematology. Observations made on the hematocrit, erythrocyte sedimentation rate, white blood cell count, and differential allow several conclusions. (1) None of these hematological measurements discriminated among the three principal variables work, water, and diet. (2) The variations rather tended to reflect a response of the organism to the total field experience. (3) The mechanisms involved were different for the several measurements. The hematocrit fell in the recovery periods in response to adjustments in the distribution of water between the blood and extravascular spaces. The leukocytes fell in the experimental periods. Virus infection and stress were implicated. The ESR was erratic presumably as a result of fluctuating temperature conditions within the laboratory. (4) In so far as these observations do not assist in physiologically discriminating among the experimental regimens, they support the work of Sargent et al. (1954).

TABLE III. 103

PRE-PERIOD DATA ON HEMATOCRIT
(Packed Cell Vol., %)

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
Flight 1	49	3.3	6.6	47	3.0	6.4
Flight 2	49	3.3	6.7	49	3.0	6.0
Flight 3	48	2.2	4.6	46	1.9	4.2
Flight 4	50	2.5	5.0	49	2.6	5.3
Controls	48	1.7	3.5	47	2.4	5.1

TABLE III. 104

HEMATOCRIT
(Packed Cell Vol., %)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	48	47	46	40	44	47	49	48	44	42
	L	48	48	46	40	45	50	51	51	42	43
0/100/0	U	48	50	47	42	42	48	48	46	43	44
1000	L	49	48	50	42	48	51	50	50	42	42
0/100/0	U	44	44	45	40	42	48	48	48	44	44
2000	L	45	46	46	42	46	48	48	48	43	46
2/20/78	U	51	50	52	44	45	46	48	52	46	44
1000	L	48	50	50	44	48	50	47	48	44	44
2/20/78	U	48	47	53	44	44	45	47	48	42	43
2000	L	53	45	48	46	48	49	48	50	44	44
15/52/33	U	46	46	52	41	42	46	48	50	42	41
1000	L	49	48	48	42	46	47	44	44	41	42
15/52/33	U	46	44	45	42	43	47	46	48	44	45
2000	L	51	48	48	43	46	50	48	48	42	44
15/52/33	U	46	44	44	42	43	48	48	48	46	46
3000	L	47	46	46	41	46	51	46	48	46	46
30/0/70	U	49	47	52	44	44	49	48	51	44	44
1000	L	48	46	48	42	45	48	47	49	42	46
30/0/70	U	52	48	51	45	46	45	44	46	44	44
2000	L	48	46	48	43	46	48	47	48	44	43
Control	U	46	45	46	44	46	49	47	48	47	47
	L	47	44	45	43	46	49	44	46	46	46

*Mean values for PI and PII.

TABLE III. 105

SIGNIFICANCE OF DIFFERENCES IN HEMATOCRIT
BETWEEN PRE-PERIOD AND RECOVERY BY "t" TEST*

Pre-Period II	Recovery I Data	Recovery I "t"	Recovery II Data	Recovery II "t"
Flight 1 (47 ± 3.0)**	Flight 1 (42 ± 2.3)	5.84	Flight 1 (43 ± 2.3)	4.72
Flight 2 (49 ± 3.0)	Flight 2 (42 ± 2.3)	8.46	Flight 2 (46 ± 1.9)	3.87
Flight 3 (46 ± 1.9)	Flight 3 (44 ± 1.7)	3.45	Flight 3 (44 ± 1.9)	3.38
Flight 4 (49 ± 2.6)	Flight 4 (43 ± 1.8)	8.41	Flight 4 (44 ± 2.5)	6.10

*If "t" is greater than 2.576, P is less than 0.01.
**Values in parentheses = mean ± s.d.

TABLE III. 106

INCIDENCE OF UPPER RESPIRATORY INFECTIONS
AND OTHER ILLNESSES: FEBRUARY 22 TO APRIL 5, 1954

A. ACUTE UPPER RESPIRATORY INFECTIONS*

Period	Flight 1	Flight 2	Flight 3	Flight 4
PRE I	1	1	3	6
PRE II	5	1	1	6
EXP I	5	5	3	10
EXP II	3	0	0	4
REC I	0	0	1	2
REC II	2	0	0	0

*Experimental subjects and flight leaders

B. OTHER ILLNESSES

1. Emergency Dental Extractions
   No. 72 in EXP I
   No. 81 in P II with ?periapical abcess in EXP I
   No. 85 in REC I

2. Gingitivitis
   No. 73 in EXP II
   No. 75 in EXP I

3. Genito-Urinary Infection
   No. 71, phimosis and balanitis in REC I

TABLE III. 107

SUBJECTS WITH PERSISTENTLY HIGH ERYTHROCYTE SEDIMENTATION RATES

Subject Code No.	Erythrocyte Sedimentation Rate, mm/hr						Remarks
	Pre		Exp		Rec		
	I	II	I	II	I	II	
19	12	30	9	16	19	22	Idiopathic
52	11	22	21	30	32	29	Idiopathic
58	28	21	30	26	27	28	Bronchial asthma
65	11	14	20	15	20	15	Idiopathic
76	22	25	26	34	18	17	Idiopathic
79	16	26	16	13	5	4	Idiopathic
80	13	10	29	23	22	6	Idiopathic
84	18	33	15	25	35	12	?Rheumatic fever

TABLE III. 108

ROOM TEMPERATURE* AT TIME OF
MEASURING ERYTHROCYTE SEDIMENTATION RATES

Period (Date)	Flights 1 & 2	Flights 3 & 4
PRE I (F26/27)	72 ± 1°F	70 ± 2°F
PRE II (M3/4)	85 ± 5°F	70 ± 2°F
EXP I (M13)	75 ± 5°F	75 ± 5°F
EXP II (M19)	75 ± 5°F	75 ± 5°F
REC I (M26/27)	85 ± 5°F	84 ± 4°F
REC II (A2/3)	90 ± 5°F	76 ± 4°F

*From recording thermograph.

TABLE III. 109

PRE-PERIOD DATA ON ERYTHROCYTE SEDIMENTATION RATE
(mm/hr)

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
Flight 1*	6	3.3	55.0	10	6.6	66.0
Flight 2$^{\alpha}$	6	3.6	60.0	3	2.4	80.0
Flight 3	8	3.8	47.5	7	4.8	68.5
Flight 4$^{\beta}$	10	5.0	50.0	13	6.8	52.0
Controls$^{\gamma}$	6	2.8	46.5	9	6.3	70.0

*Difference between P I and P II significant at 2% level.

$^{\alpha}$Difference between P I and P II significant at 1% level.

$\beta_t = 1.28$, P = .20

$\gamma_t = 1.57$, P = .15

TABLE III. 110

ERYTHROCYTE SEDIMENTATION RATE
(mm/hr)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	6	9	8	6	13	15	7	7	8	10	1	4
	L	4	3	10	6	0	4	7	8	9	6	2	3
0/100/0 1000	U	4	13	6	8	16	12	8	4	6	12	2	6
	L	8	3	5	8	0	8	6	8	12	9	4	0
0/100/0 2000	U	11	6	0	12	6	10	8	12	12	18	16	16
	L	3	1	4	6	8	6	8	16	7	10	6	4
2/20/78 1000	U	6	6	6	10	2	10	8	12	9	9	3	8
	L	4	3	6	6	5	6	14	18	16	18	14	5
2/20/78 2000	U	6	10	2	15	10	15	7	6	11	5	3	6
	L	8	8	2	5	3	5	8	12	8	6	10	5
15/52/33 1000	U	2	8	5	14	4	8	11	4	10	6	3	1
	L	8	3	16	8	2	8	4	4	2	0	0	0
15/52/33 2000	U	10	20	8	16	14	16	1	2	8	3	1	0
	L	11	4	12	14	4	8	16	18	13	7	9	8
15/52/33 3000	U	2	7	3	3	6	5	8	10	14	10	12	12
	L	5	2	8	7	1	4	8	10	11	8	4	2
30/0/70 1000	U	8	9	4	13	8	10	12	8	4	11	8	9
	L	4	3	18	25	4	23	16	20	18	34	20	15
30/0/70 2000	U	8	11	7	12	9	12	9	7	2	8	8	5
	L	2	2	2	6	1	8	9	12	6	20	6	10
Control	U	8	5	12	20	20	11	4	4	6	7	4	3
	L	4	11	16	13	16	8	6	16	16	12	9	1

TABLE III. 111

PRE-PERIOD DATA ON WHITE BLOOD CELLS

(thousands/mm^3)

Groups of Subjects	P I Mean	P I Range	P II Mean	P II Range	P I Mean	P I Range	P II Mean	P II Range
	A. Total White Cell Count				D. Monocytes			
Flight 1	9.16	5.00-13.25	10.27	6.75-13.35	57	0-242	57	0-368
Flight 2	7.80	3.50-14.60	10.33	6.50-14.80	66	0-452	138	0-544
Flight 3	9.24	6.25-12.80	10.07	6.95-14.00	125	0-336	31	0-103
Flight 4	8.57	4.50-11.30	9.21	4.85-12.60	91	0-400	70	0-420
Controls	7.69	5.40-11.70	9.63	4.90-16.00	51	0-237	63	0-320
	B. Neutrophils				E. Eosinophils			
Flight 1	5.20	3.02-8.24	6.06	3.79-9.36	217	0-820	283	0-738
Flight 2	4.52	2.00-8.38	5.57	3.60-8.56	352	0-1710	409	0-1680
Flight 3	5.34	3.13-8.32	5.75	3.64-8.36	175	0-476	201	0-621
Flight 4	4.76	2.30-6.81	5.06	2.66-7.06	172	0-746	259	72-890
Controls	4.55	3.29-8.20	6.75	2.89-10.70	147	0-316	300	84-496
	C. Lymphocytes				F. Basophils			
Flight 1	3.62	1.60-5.35	3.86	2.03-5.93	30	0-121	4	0-88
Flight 2	3.03	1.20-6.86	4.02	2.66-5.92	18	0-146	13	0-146
Flight 3	3.55	2.46-4.92	3.97	2.38-6.06	34	0-260	23	0-206
Flight 4	3.54	2.20-5.20	3.79	2.40-5.42	26	0-178	43	0-171
Controls	2.94	1.89-3.88	3.76	1.81-5.51	48	0-168	28	0-160

TABLE III. 112

TOTAL WHITE BLOOD CELL COUNT
(thousands/mm^3)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	8.72	7.12	6.28	7.15	7.48	8.31	7.27	8.38	8.90	10.15
	L	8.26	6.95	5.15	6.06	9.60	8.94	7.32	5.90	7.88	7.67
0/100/0	U	10.12	8.70	8.95	9.28	10.85	8.55	7.48	10.15	9.46	9.75
1000	L	12.03	6.38	6.20	9.60	10.55	8.62	7.00	6.05	8.02	6.10
0/100/0	U	9.53	9.60	7.95	8.90	9.72	12.51	10.60	10.78	9.72	10.95
2000	L	9.56	7.28	6.18	9.28	10.45	9.31	9.65	6.60	8.72	7.52
2/20/78	U	9.68	10.00	7.72	8.20	9.12	9.97	9.80	8.78	10.90	12.10
1000	L	6.88	8.15	6.22	7.25	9.70	10.41	8.78	6.50	8.85	9.85
2/20/78	U	11.68	9.62	11.27	8.05	10.42	10.42	10.23	6.35	8.20	10.97
2000	L	8.46	7.78	8.62	8.92	11.12	9.15	8.32	6.25	6.20	10.80
15/52/33	U	10.47	8.85	11.02	9.20	13.05	10.11	8.80	7.65	11.28	9.42
1000	L	8.04	9.08	6.48	5.05	8.82	7.81	7.30	6.25	9.20	9.55
15/52/33	U	9.91	7.30	7.15	9.08	10.02	8.28	9.45	7.85	11.30	9.60
2000	L	11.16	12.40	10.45	7.75	10.42	7.90	8.02	7.10	8.30	7.65
15/52/33	U	10.42	10.15	7.65	8.85	9.68	9.96	11.00	8.58	10.25	10.80
3000	L	8.30	6.85	7.50	8.35	10.12	9.02	7.42	7.32	8.88	8.07
30/0/70	U	9.21	12.08	10.55	9.60	11.05	9.40	8.18	7.35	9.25	10.18
1000	L	7.40	7.68	8.35	8.08	10.20	8.60	8.85	14.80	7.52	9.15
30/0/70	U	8.41	9.18	9.92	9.05	7.75	9.31	8.02	6.20	7.90	9.82
2000	L	11.40	7.30	10.85	10.32	10.45	9.10	9.18	8.78	7.40	9.60
Control	U	7.23	6.97	8.83	7.00	6.15	9.49	9.28	7.40	7.73	9.83
	L	7.72	8.65	7.08	6.87	9.13	10.19	9.82	8.50	9.80	7.48

*Mean values for PI and PII.

TABLE III. 113

TOTAL WHITE BLOOD CELL COUNT: STATISTICAL ANALYSIS

A. FREQUENCY DISTRIBUTION

Class Intervals (thousands/mm^3)	Frequency Distribution, %			
	P I & P II	E I	E II	R I & R II
3.0-3.9	1.03	0.00	0.00	0.51
4.0-4.9	1.55	2.02	4.16	1.01
5.0-5.9	4.64	8.08	12.50	4.56
6.0-6.9	10.81	15.15	19.80	9.13
7.0-7.9	11.32	15.15	21.85	14.70
8.0-8.9	19.07	19.19	12.50	20.30
9.0-9.9	14.42	15.15	10.42	16.75
10.0-10.9	15.98	12.12	7.29	15.75
11.0-11.9	7.20	3.03	5.21	8.62
12.0-12.9	6.17	5.05	1.04	4.56
13.0-13.9	5.14	4.04	3.25	3.04
14.0-14.9	1.55	1.01	1.04	0.51
15.0-15.9	0.52	0.00	1.04	0.00
16.0-16.9	0.52	0.00	0.00	0.00
Total	99.82	99.99	100.10	99.44

B. CHI-SQUARE TESTS

Test	d.f.	X^2	P
PI vs. PII	13	18.73	> 0.05
PI&PII vs. EI	13	7.53	> 0.05
PI&PII vs. EII	13	28.23	< 0.01
RI vs. RII	11	30.34	< 0.01
PI&II vs. RI	13	13.36	> 0.05
PI&II vs. RII	13	14.24	> 0.05

TABLE III. 114

NEUTROPHIL COUNT

(thousands/mm^3)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	5.03	4.62	4.01	5.01	4.52	4.91	4.30	4.95	4.71	5.73
	L	5.28	4.12	3.54	3.49	5.63	4.50	3.67	3.68	4.15	4.25
0/100/0	U	5.66	5.03	5.30	4.91	6.67	4.32	3.81	5.93	5.63	5.17
1000	L	6.07	3.16	2.86	4.99	3.84	4.82	4.29	3.35	4.09	3.13
0/100/0	U	5.30	6.08	4.65	5.34	5.86	7.34	6.65	6.35	6.12	7.08
2000	L	5.09	4.51	3.09	4.77	5.98	5.00	5.23	3.36	4.61	4.00
2/20/78	U	5.42	5.66	4.39	4.38	4.89	5.55	5.70	5.08	6.50	6.58
1000	L	3.99	4.84	4.02	4.01	6.08	6.05	5.26	3.80	5.32	6.05
2/20/78	U	7.01	6.00	7.57	4.64	6.63	6.21	6.24	3.46	4.39	7.50
2000	L	4.44	4.28	4.09	4.46	5.42	4.81	4.49	3.36	3.18	6.21
15/52/33	U	6.25	5.24	6.97	5.15	8.23	5.69	5.77	4.26	6.34	5.60
1000	L	4.54	5.58	3.72	2.84	5.23	4.40	3.72	3.25	4.68	5.32
15/52/33	U	5.75	4.38	4.12	4.83	5.86	4.40	5.52	4.35	6.42	5.39
2000	L	6.79	8.25	6.45	4.70	5.63	4.28	4.40	4.62	5.31	3.93
15/52/33	U	6.21	5.97	4.56	4.90	6.00	6.09	6.66	4.56	6.26	6.63
3000	L	4.70	4.08	4.46	4.89	6.09	5.27	4.26	4.28	5.09	5.66
30/0/70	U	5.39	8.09	7.66	6.13	7.49	5.62	4.67	4.47	4.10	6.07
1000	L	4.22	4.80	5.07	4.69	5.63	5.00	5.03	8.70	4.40	5.65
30/0/70	U	4.90	5.92	6.58	5.76	5.20	5.46	4.70	3.30	4.42	5.58
2000	L	6.90	7.02	7.02	6.49	6.30	5.16	5.01	4.25	4.25	5.34
Control	U	4.02	3.77	4.91	3.71	3.47	5.47	5.32	4.17	4.59	5.69
	L	4.27	5.40	3.90	4.16	5.72	6.49	6.25	4.94	5.59	4.75

*Mean values for PI and PII.

TABLE III. 115

NEUTROPHIL COUNT: STATISTICAL ANALYSIS

A. FREQUENCY DISTRIBUTION

Class Intervals (thousands/mm^3)	Frequency Distribution, %			
	P I & P II	E I	E II	R I & R II
1.0-1.9	0.00	0.00	0.00	0.50
2.0-2.9	3.66	8.10	13.50	3.60
3.0-3.9	15.20	19.20	26.00	12.30
4.0-4.9	27.20	27.30	28.10	30.10
5.0-5.9	26.20	19.20	14.60	25.00
6.0-6.9	14.70	16.20	7.30	18.40
7.0-7.9	7.30	3.00	5.20	8.20
8.0-8.9	4.70	6.10	2.10	2.00
9.0-9.9	0.20	1.00	3.10	0.00
10.0-10.9	0.20	0.00	0.00	0.00
Total	99.36	100.10	99.90	100.10

B. CHI-SQUARE TESTS

Test	d.f.	X^2	P
PI vs. PII	8	12.59	> 0.05
PI&PII vs. EI	8	7.51	> 0.05
PI&PII vs. EII	8	22.77	< 0.01
RI vs. RII	7	24.60	< 0.01
PI&PII vs. RI	8	15.78	0.05
PI&PII vs. RII	9	14.20	> 0.05

TABLE III. 116

LYMPHOCYTE COUNT

(thousands/mm^3)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	3.20	2.70	2.51	3.34	2.69	3.13	2.82	3.16	3.34	2.69
	L	3.17	2.73	1.96	2.49	3.76	3.93	3.07	2.57	2.49	3.76
0/100/0	U	3.86	3.63	3.37	3.87	3.74	3.78	3.50	4.13	3.87	3.74
1000	L	4.87	2.30	2.26	3.80	3.00	3.27	2.39	2.05	3.81	3.00
0/100/0	U	3.80	3.32	3.02	3.34	3.58	4.54	3.91	3.99	3.34	3.58
2000	L	4.17	2.52	2.78	4.23	4.36	3.99	4.18	2.99	4.23	4.37
2/20/78	U	3.94	4.08	5.09	3.19	3.28	4.06	2.88	3.10	3.19	3.28
1000	L	2.78	3.11	2.36	2.78	3.98	3.92	3.55	2.50	2.78	3.98
2/20/78	U	4.25	3.48	3.47	3.12	3.23	3.94	3.41	2.64	3.13	3.23
2000	L	3.40	2.76	3.73	3.31	4.60	4.00	3.55	2.63	3.31	4.60
15/52/33	U	4.18	3.19	3.72	3.83	3.98	3.99	2.75	3.08	3.83	3.98
1000	L	3.15	3.38	2.59	2.04	3.29	3.36	3.33	2.85	2.04	3.29
15/52/33	U	3.86	2.80	2.58	3.61	3.46	3.62	3.57	3.40	3.61	3.46
2000	L	4.02	4.10	3.63	2.81	4.32	3.83	3.32	2.25	2.81	4.33
15/52/33	U	3.86	3.66	2.56	3.43	3.27	3.59	4.05	2.80	3.43	3.27
3000	L	3.37	2.09	2.52	2.66	3.56	3.69	3.04	2.76	2.66	3.56
30/0/70	U	3.71	3.81	2.76	3.09	3.40	3.55	3.24	2.63	3.09	3.39
1000	L	2.67	2.79	3.09	2.99	4.03	3.29	3.46	3.09	2.98	4.03
30/0/70	U	3.34	3.04	3.68	2.94	2.43	3.64	3.56	2.32	2.95	2.43
2000	L	3.98	2.21	3.61	3.58	4.06	3.64	3.80	3.78	3.58	4.05
Control	U	2.93	2.78	3.57	2.87	2.40	3.73	3.94	2.91	2.93	4.08
	L	3.22	2.98	2.70	2.39	2.92	3.54	3.24	3.23	3.70	2.52

*Mean values for PI and PII.

TABLE III. 117

LYMPHOCYTES: STATISTICAL ANALYSIS

A. FREQUENCY DISTRIBUTION

Class Intervals (thousands/mm^3)	Frequency Distribution, %			
	P I & P II	E I	E II	R I & R II
1.00-1.49	1.0	0.0	1.0	0.0
1.50-1.99	1.6	4.0	7.3	4.6
2.00-2.49	6.8	16.2	20.8	7.1
2.50-2.99	14.1	18.2	25.0	21.4
3.00-3.49	22.5	27.3	16.7	22.4
3.50-3.99	22.0	21.2	17.7	19.9
4.00-4.49	15.7	5.0	6.2	13.8
4.50-4.99	6.8	7.1	2.1	7.7
5.00-5.49	5.7	0.0	2.1	1.0
5.50-5.99	2.6	1.0	0.0	2.0
6.00-6.49	0.5	0.0	1.0	0.0
6.50-6.99	0.5	0.0	0.0	0.0
Total	99.8	100.0	99.9	99.9

B. CHI-SQUARE TESTS

Test	d.f.	X^2	P
PI vs. PII	11	20.50	0.05
PI&PII vs. EI	11	22.56	0.02
PI&PII vs. EII	11	37.11	< 0.01
RI vs. RII	8	9.80	> 0.05
PI&PII vs. RI&RII	11	16.44	> 0.05

TABLE III. 118

BASOPHIL COUNT

(cells/mm^3)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	19	12	42	60	93	12	0	67	32	0
	L	0	49	13	32	21	90	96	39	0	0
0/100/0	U	46	96	43	81	113	65	0	0	0	0
1000	L	63	0	0	60	0	0	0	72	0	0
0/100/0	U	0	46	42	48	43	31	0	0	0	0
2000	L	0	0	112	0	0	68	47	0	87	0
2/20/78	U	30	0	145	86	41	43	98	48	0	0
1000	L	16	56	147	0	50	26	0	65	52	61
2/20/78	U	0	0	113	0	104	19	62	65	50	109
2000	L	0	40	40	0	0	0	40	28	62	0
15/52/33	U	0	0	0	0	0	26	0	45	69	0
1000	L	31	0	29	23	0	0	0	125	43	0
15/52/33	U	0	0	40	40	100	0	66	0	80	131
2000	L	0	0	0	0	0	0	0	142	83	84
15/52/33	U	45	0	32	0	38	23	70	0	0	0
3000	L	20	36	37	43	55	0	42	35	89	50
30/0/70	U	19	0	0	0	0	0	33	44	185	0
1000	L	0	45	0	46	112	126	34	0	37	0
30/0/70	U	0	92	0	0	45	75	120	50	91	55
2000	L	0	0	0	0	55	27	0	43	74	75
Control	U	81	60	23	31	63	28	0	0	0	36
	L	0	33	45	0	0	48	92	21	0	0

*Mean values for PI and PII.

TABLE III. 119

BASOPHIL COUNT: STATISTICAL ANALYSIS

A. FREQUENCY DISTRIBUTION

Class Intervals ($cells/mm^3$)	Frequency Distribution, number				
	P I & P II	E I	E II	R I	R II
0-49	149	73	57	67	68
50-99	18	15	24	22	12
100-149	14	6	11	3	12
150-199	8	4	2	5	1
200-249	1	1	1	2	4
250-299	1	0	1	0	0
Total	191	99	96	99	97
Mean	21	22	32	26	28

B. CHI-SQUARE TESTS

Test	d.f.	X^2	P
PI&PII vs. EI	5	2.84	>0.05
PI&PII vs. EII	5	16.08	<0.01
PI&PII vs. RI	5	11.78	0.05
PI&PII vs. RII	5	9.04	>0.05

TABLE III. 120

EOSINOPHIL COUNT

(cells/mm^3)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	388	191	90	290	129	196	123	222	388	275
	L	279	49	154	163	151	205	260	238	258	229
0/100/0	U	444	491	452	359	382	142	120	110	516	470
1000	L	995	552	874	1032	140	463	292	446	680	383
0/100/0	U	220	96	118	172	249	186	56	216	391	328
2000	L	121	97	198	233	158	233	240	226	423	316
2/20/78	U	144	63	230	367	241	259	628	324	471	800
1000	L	296	164	165	313	97	183	375	0	88	99
2/20/78	U	127	143	45	247	444	241	330	129	528	235
2000	L	552	625	777	890	1011	172	127	35	143	214
15/52/33	U	273	261	283	223	646	360	254	234	407	229
1000	L	216	181	122	146	145	90	102	63	149	28
15/52/33	U	239	123	415	646	441	85	255	53	645	375
2000	L	459	65	268	146	305	157	241	71	41	126
15/52/33	U	262	351	370	284	366	165	110	223	255	216
3000	L	279	385	113	421	320	45	83	143	228	238
30/0/70	U	107	120	68	234	161	160	99	164	385	259
1000	L	201	0	32	305	213	126	266	227	346	263
30/0/70	U	146	60	129	129	78	71	313	175	328	362
2000	L	466	166	101	101	50	191	176	176	269	193
Control	U	258	363	220	298	216	212	151	221	183	25
	L	249	250	303	226	269	267	163	273	372	170

*Mean values for PI and PII.

TABLE III. 121

EOSINOPHIL COUNT: STATISTICAL ANALYSIS

A. FREQUENCY DISTRIBUTION

Class Intervals	Frequency Distribution, number				
(cells/mm^3)	P I & P II	E I	E II	R I	R II
0-99	49	28	31	16	25
100-199	49	33	25	17	21
200-299	38	18	17	19	15
300-399	19	9	16	17	15
400-499	13	3	1	12	6
500-599	3	3	1	10	8
600-699	9	1	3	1	4
700-799	6	2	0	2	1
800-899	2	0	0	2	0
900-999	0	1	0	1	0
1000-1099	1	1	0	0	1
>1100	1	0	2	2	1
Total	191	99	96	99	97
Mean	254	210	207	329	259

B. CHI-SQUARE TESTS

Test	d.f.	X^2	P
PI vs. PII	10	18.11	> 0.05
PI&PII vs. EII	10	13.49	> 0.05
PI&PII vs. RI	11	26.78	< 0.01

TABLE III. 122

MONOCYTE COUNT
(cells/mm^3)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	58	46	0	30	88	52	23	0	57	0
	L	127	60	13	0	43	29	48	39	25	0
0/100/0	U	103	0	0	42	0	61	45	93	0	0
1000	L	32	119	237	0	41	78	58	108	162	0
0/100/0	U	43	50	118	0	0	125	0	51	97	0
2000	L	208	40	0	132	0	25	0	32	45	0
2/20/78	U	125	232	0	129	214	29	54	129	61	69
1000	L	35	0	85	42	0	257	113	115	110	160
2/20/78	U	26	0	69	372	0	113	194	65	23	30
2000	L	113	119	0	134	56	166	79	118	57	0
15/52/33	U	48	0	0	0	193	34	26	0	44	41
1000	L	125	0	65	0	168	78	146	128	43	0
15/52/33	U	58	0	0	40	0	84	24	51	0	0
2000	L	159	0	104	97	105	17	61	101	122	126
15/52/33	U	56	162	133	230	0	130	110	0	0	47
3000	L	20	108	0	124	47	64	0	105	148	0
30/0/70	U	0	53	68	146	0	73	99	44	172	56
1000	L	166	32	189	46	56	44	50	235	0	0
30/0/70	U	40	0	100	168	0	73	60	34	0	0
2000	L	59	0	0	157	0	74	48	0	55	59
Control	U	0	0	150	32	0	63	149	73	27	0
	L	126	33	50	63	220	0	72	0	56	32

*Mean values for PI and PII.

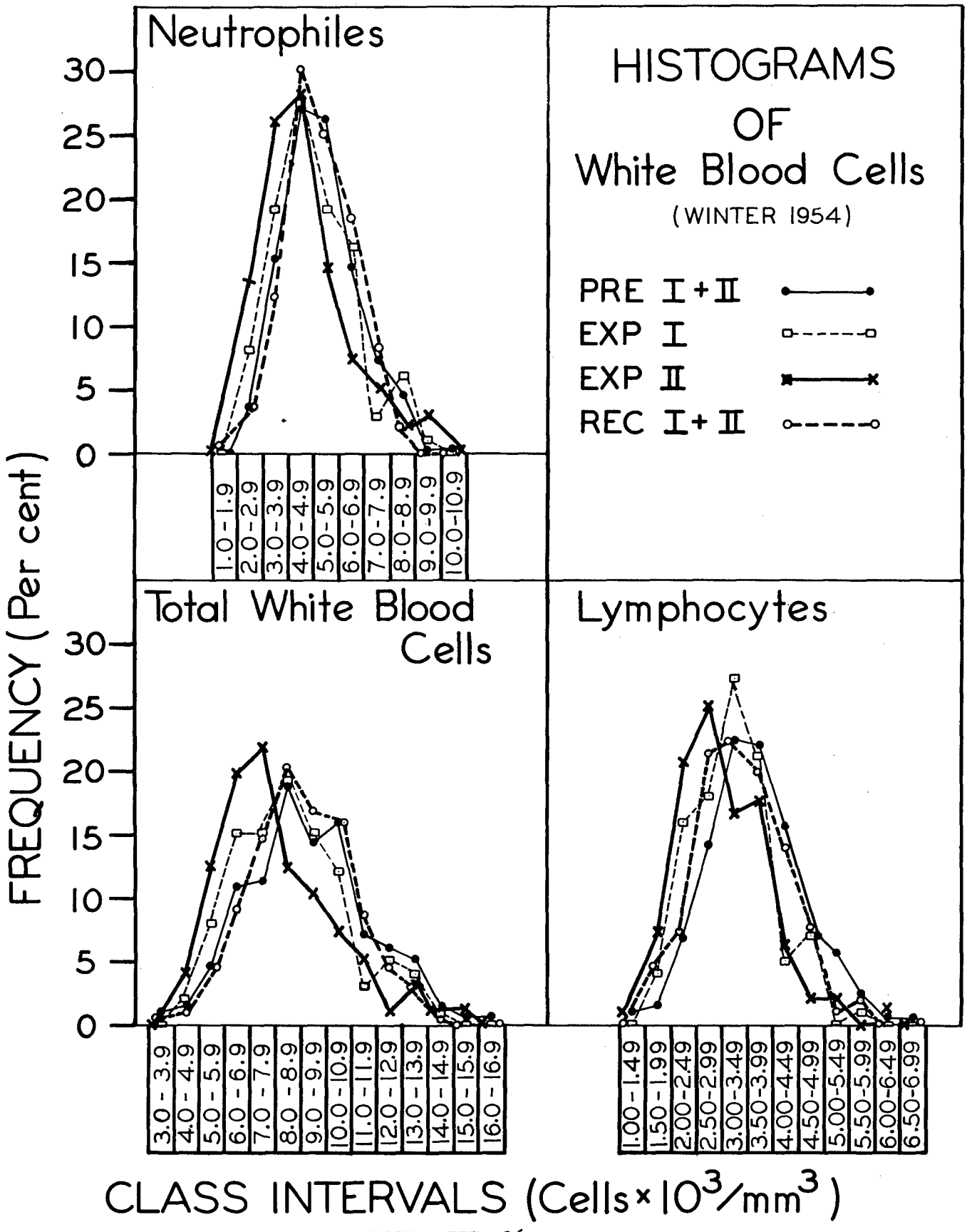

FIGURE III. 36

F. BALANCES AND INTAKES

1. Calorie Balance

Pre-Periods. Pre-period data on mean caloric intake and balances are given in Table III.123, and on daily caloric expenditure in Table III. 124. The four flights consumed about 3350 Cal/man/day in the first pre-week; in the second week, they dropped to around 3100 Cal/man/day. At the same time, they were expending about 3000. During these weeks, they were in slight positive balance, of +20 to +340 Cal/day. This small positive balance would be expected in growing young men, as the subjects were. The data are consistent with other estimates of camp life and its energy requirements.

Experimental Periods. Mean daily caloric intakes are given in Table III. 125; mean daily caloric expenditures in Table III. 124; and mean daily balance in Table III. 126. Balance data are sketched in Figures III. 37 and 38.

Calorie balance was negative in experimental periods, and positive in recovery periods. The only two contributory factors were caloric intake and caloric expenditure. Nutrient ratio and water restriction had no apparent effect.

Caloric intakes approximated closely those called for in the planning, i.e., 0 for starvation, 1000, 2000, and 3000 in the other regimens. The hard work groups averaged an expenditure of 3715 Cal/day in the first week and 3380 in the second. The light work groups averaged 3045 in the first week, and 2905 in the second. The drops were caused by an increased testing schedule. The only groups to remain in balance in the experimental periods were N-3000 U and L, light work (Figure III. 38).

Recovery Periods. The first week of recovery saw a large consumption of food and a positive balance. The second week saw a truly remarkable increase in both categories. In those who had been on hard work, intakes of over 5000 Cal/man/day occurred in 18 of 20 groups, and in those previously on light work, in 15 of 20 groups. In these same groups, positive balance of over 2000 Cal/man/day occurred in 17 of 20 groups, and 17 of 20 groups respectively.

These findings emphasize strikingly that rehabilitation after caloric restriction requires a very large food consumption to overcome the deficit previously incurred. In general, the more severe the deprivation, the more food is required for rehabilitation. Previous water intake, or protein/fat/carbohydrate ratios had, in our subjects, little if any effect on the subsequent rehabilitation intakes and balances.

TABLE III. 123

PRE-PERIOD DATA ON MEAN CALORIC INTAKE AND MEAN CALORIC BALANCE
(Cal/man/day)

Groups of Subjects	P I		P II	
	Intake	Balance	Intake	Balance
Flight 1	3410	+340	3000	+ 20
Flight 2	3430	+300	3220	+150
Flight 3	3340	+250	3290	+250
Flight 4	3270	+310	2980	+ 80

TABLE III. 124

DAILY CALORIC EXPENDITURE
(Mean and Range)

Period	Calories/day			
	Flight 1	Flight 2	Flight 3	Flight 4
PRE I	3070 2380-4470	3140 2540-3570	3090 2370-3680	2960 2550-3610
PRE II	2980 2320-4420	3070 2490-3460	3040 2400-3610	2900 2470-3520
EXP I	3700 2970-5170	3730 3040-4120	3130 2580-3650	2960 2590-3520
EXP II	3400 2620-4750	3360 2730-3730	2980 2450-3540	2830 2420-3390
REC I	3050 2370-4280	3140 2570-3550	3030 2420-3590	2990 2510-3540
REC II	3050 2460-4220	3120 2550-3590	3060 2460-3550	2910 2470-3500

TABLE III. 125

MEAN DAILY CALORIC INTAKE
(Cal/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	3100	2910	0	0	4500	6360	3380	3100	0	0	4010	6210
	L	3480	3340	0	0	4540	6520	3420	2980	0	0	4320	5250
0/100/0	U	3470	3310	1000	980	4960	6280	3460	3240	990	980	4060	5270
1000	L	3920	3570	1100	1140	4380	6080	3150	2920	1000	1000	4100	5000
0/100/0	U	3380	3110	2000	1980	5140	6340	3520	3070	1990	1970	4210	5480
2000	L	3390	2760	2000	2000	3720	4980	3330	3080	2000	2000	4210	5100
2/20/78	U	4290	3250	1000	1000	4590	6320	2100	3080	970	1000	4360	6060
1000	L	2890	2630	1000	1000	3630	6760	3450	3020	1000	1000	3940	5380
2/20/78	U	4070	3611	2000	2000	4560	5290	3390	3370	1835	2000	5160	6550
2000	L	3720	3440	2000	2000	4140	6020	3500	3310	2000	2000	4550	5470
15/52/33	U	3560	2990	1120	1120	5020	6270	3600	3430	1120	1120	4350	6370
1000	L	3500	3230	1120	1120	4190	5670	3210	2940	1120	1120	3850	4580
15/52/33	U	3230	3100	2000	2000	4500	5660	3730	3480	2000	2000	4030	4880
2000	L	3200	3530	2000	2000	3940	6270	2890	2800	2000	2000	3340	4860
15/52/33	U	3750	3160	2990	2990	3310	4870	3440	3220	2990	2880	4500	6000
3000	L	3420	3410	3010	2990	3570	5070	3300	3060	2990	2990	3740	4610
30/0/70	U	2322	2658	980	1000	4770	6750	3750	3310	950	1020	4780	6400
1000	L	3756	3350	1000	1000	4260	6000	3220	2950	1000	1040	4110	5390
30/0/70	U	2930	2420	1940	1990	3800	5120	2950	3110	1920	1950	4150	5060
2000	L	3060	2970	1540	1970	4620	6880	3160	2780	1990	1870	4260	5460

TABLE III. 126

MEAN DAILY CALORIC BALANCE
(Cal/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	+ 200	+ 80	-3530	-3240	+1670	+3480	+180	- 40	-3180	-3060	+ 980	+3080
	L	+ 250	+ 160	-3810	-3420	+1310	+3290	+340	- 80	-3040	-2900	+1320	+2550
0/100/0	U	+ 600	+ 510	-2460	-2660	+2150	+3440	+660	+470	-1850	-1700	+1340	+2980
1000	L	+ 760	+ 460	-2660	-2250	+1220	+3000	+220	+ 40	-1920	-1800	+1180	+2140
0/100/0	U	- 190	- 170	-1980	-1820	+1640	+2880	+460	+ 70	-1080	- 960	+1220	+2520
2000	L	+ 560	0	-1400	-1120	+ 920	+2260	+120	- 60	-1200	-1080	+1020	+1940
2/20/78	U	+1030	+ 40	-2900	-2500	+1340	+3120	-900	+160	-2050	-1880	+1470	+3100
1000	L	0	- 200	-2480	-2140	+ 720	+3840	+480	+120	-1940	-1830	+1040	+2460
2/20/78	U	+1000	+ 370	-1970	-1900	+1540	+2260	+120	+660	-1510	-1190	+1910	+3290
2000	L	+ 240	+ 130	-2020	-1620	+ 840	+2680	+410	+280	-1100	- 960	+1460	+2420
15/52/33	U	+ 680	+ 190	-2360	-2040	+2120	+3400	+920	+770	-1660	-1520	+1710	+3660
1000	L	+ 320	+ 100	-2660	-2300	+ 980	+2510	+450	+260	-1640	-1540	+1080	+1900
15/52/33	U	+ 310	+ 240	-1600	-1380	+1540	+2680	+200	0	-1540	-1440	+ 550	+1460
2000	L	+ 460	+ 130	-1980	-1570	+ 560	+2880	+220	- 20	- 940	- 810	+ 520	+2040
15/52/33	U	+ 720	+ 180	- 740	- 480	+ 310	+1880	+320	+110	- 200	- 200	+1300	+2800
3000	L	+ 160	+ 210	- 940	- 690	+ 300	+1860	+340	+140	- 20	+ 60	+ 740	+1660
30/0/70	U	- 180	+ 200	-2180	-1780	+2180	+4120	+550	+170	-2300	-2000	+1700	+3270
1000	L	+ 740	+ 380	-2660	-2200	+1120	+3020	+220	+ 20	-1980	-1780	+1190	+2460
30/0/70	U	- 960	-1360	-2640	-2200	- 20	+1360	+130	+350	- 920	- 830	+1260	+2170
2000	L	+ 140	+ 120	-1920	-1180	+1630	+3900	+520	+190	- 680	- 660	+1510	+2780

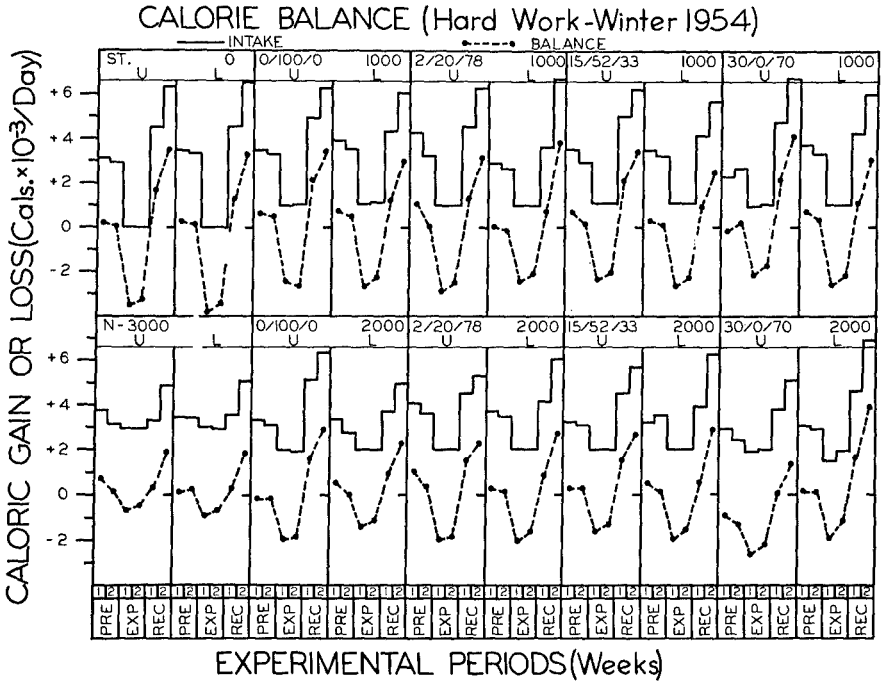

FIGURE III. 37. CALORIE BALANCE (HARD WORK), WINTER, 1954.

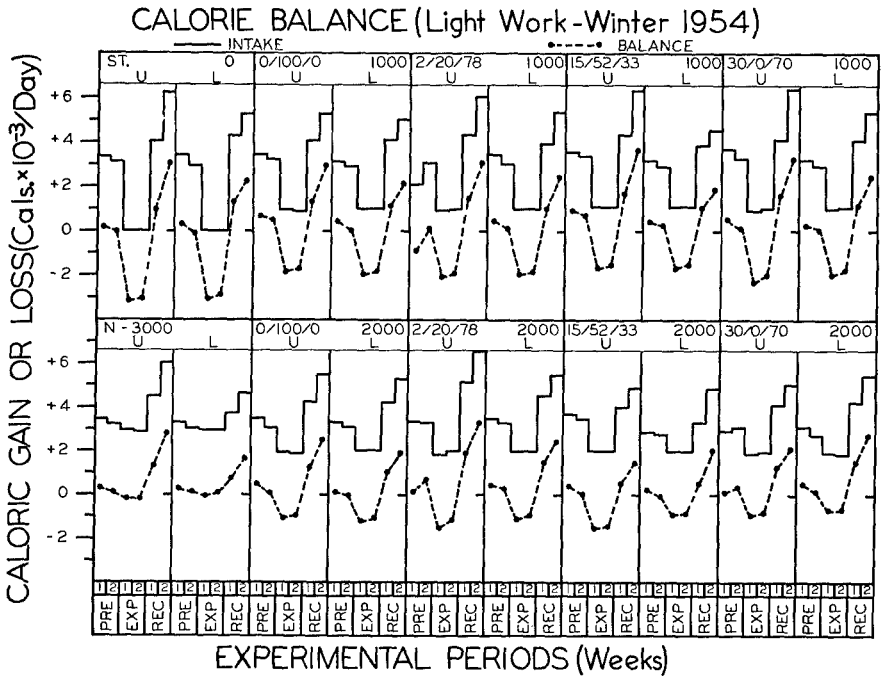

FIGURE III. 38. CALORIE BALANCE (LIGHT WORK), WINTER, 1954.

2. Water Balance

The average data for water balance in the hard work groups are given in Figure III. 39 and for light work in Figure III. 40. For these groups the intakes are given in Table III. 127 and the balances in Table III. 128. It should be borne in mind that these intakes include liquid water, water already in the food preformed, and water formed in the body by combustion of foodstuffs.

Pre-Periods. During pre-periods, total water intake for all groups was quite close to three liters per day, and balances varied but little from zero (Tables III. 127 and 128). There was a tendency for both to decrease slightly in P II. There was nothing abnormal or unusual about water balance in the two pre-period weeks.

Experimental Periods. The most interesting finding in experimental periods was that all subjects, regardless of regimen, water intake, or work load, tended to be in negative water balance. So far as the specific factors are concerned, the hard work groups displayed the greatest negative balance for any given regimen, presumably because of their sweating. Negativity was affected by calorie intake: 3000 Cal tended to produce the least negative balances; starvation the greatest; and 1000 and 2000 Cal intermediate degrees.

Water intake did not play the decisive role that one would expect, because only in one regimen (N 3000 U) did the subjects with unlimited water drink enough to remain in balance in EXP II. The thirst mechanisms were profoundly affected by the various regimens, as has been noted by others and by us in the temperate study of 1953, so that even when water was given in unlimited amounts, the subjects underwent "voluntary dehydration" because they were not thirsty enough to cover the complete water deficit. In general, those regimens with the lowest osmotic loads were the least thirst provoking (pure carbohydrate, especially) as will be seen in Table III. 129 where thirst provoking qualities are measured by comparing voluntary intake with that during limitation of water. The smaller this difference, the less thirst provoking is the regimen. In both groups, pure carbohydrate was least thirst provoking, and N 3000 and 30/0/70 2000 were high on the list.

So far as the specific properties of the nutrient mixtures is concerned, two factors are important: calories and osmotic load. By contributing to the metabolic water, increasing calorie intakes tend to decrease the negative water balance. By increasing the obligatory water requirements to dispose of solutes, those regimens with high osmotic loads tended to increase the water deficit; data are presented in Table III. 130, where the water balances in EXP II for the limited water groups are given. A balance is struck between the aggravating effects of osmotic load and the alleviating effects of increasing the caloric intake. When more calories of a low osmotic regimen are added, water balance becomes less negative (0/100/0); when more calories of a moderate osmotic regimen are added, there is little consistent effect (2/20/78, 15/52/33); and when more calories of a high osmotic regimen are added, there is a deleterious effect (30/0/70). Thus, the "water deficit potential" of a regimen can be explained in terms of its caloric content and its osmotic effects.

How can the one constant finding in all groups regardless of nutrient mixture or water intake --- tendency to negative water balance --- be explained? We tend to the view that there was an obligatory water deficit in almost all subjects associated with their weight loss, as discussed in the section on Body Composition. Each kilogram lost would entail the loss of 650 ml of preformed water, and some 500 ml of water associated with the osmotically active substances produced from the body tissue. Thus, we would expect all except the 3000-Calorie regimens to go into water deficit as a result of tissue wastage, and unlimited water alone would not keep them in balance. It is also possible that there was a continuous cold diuresis.

Recovery Periods. In recovery, water deficits for the most part were restored in the first week, when all subjects were allowed fluids in unlimited quantities. In the second week, balance was achieved, or at the most there was only a small positive balance. These changes were associated with restoration of all other nutrient balances during the recovery period.

TABLE III. 127

WATER INTAKE
(ml/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	3170	3040	1460	1290	3675	3815	2810	2830	1530	1700	3388	3660
	L	3300	3300	910	920	3920	3860	3350	2840	920	890	3900	3405
0/100/0	U	3420	2730	2190	1880	4030	3730	2720	2880	1290	1140	3365	3670
1000	L	3430	3700	1100	1110	4175	3940	3090	2710	1090	1090	3790	3395
0/100/0	U	2930	2580	1190	1570	3830	3500	2840	2780	1920	1690	3355	3515
2000	L	2760	2380	1260	1260	2995	3400	3470	3250	1170	1260	4165	4105
2/20/78	U	3610	3200	2070	1860	4235	3775	3140	3060	1720	2020	3605	3810
1000	L	2500	2190	1050	1070	3200	3580	2840	2560	1060	1060	3335	3330
2/20/78	U	3830	4040	2880	2390	3965	3570	3550	3580	2583	3493	4640	4665
2000	L	3310	3180	1220	1220	4230	4365	2900	2960	1220	1220	3725	3505
15/52/33	U	3150	2980	1840	2210	3840	3960	3300	3070	1500	1510	3225	3950
1000	L	3680	3510	1080	1120	4460	4335	2630	2740	1140	1140	3217	3165
15/52/33	U	2490	2780	1840	2140	3740	3380	3040	2930	2160	1780	3595	3005
2000	L	3300	3870	1340	1330	4115	4760	3030	2740	1360	1330	3390	3500
15/52/33	U	3410	3330	2450	2750	3390	3380	3140	3130	2290	2470	4115	3725
3000	L	2820	2840	1510	1510	3435	3370	3080	2960	1700	1580	3850	3170
30/0/70	U	2320	2540	2190	2430	3560	3605	3100	2860	1914	1780	3570	3995
1000	L	3040	2870	1110	1110	3560	4010	3330	2910	1100	1120	4095	3555
30/0/70	U	2540	2320	2250	2440	3090	3900	2540	2670	2590	2550	3285	3355
2000	L	3100	3050	1150	1240	4450	4170	2790	2690	1170	1180	3950	3110

TABLE III. 128

WATER BALANCE
(L/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	+0.46	+0.23	-1.49	-1.14	+1.33	+0.76	+0.12	+0.13	-1.40	-1.06	+0.71	+0.56
	L	+0.48	+0.44	-1.40	-1.18	+1.38	+1.14	+0.71	+0.18	-0.88	-0.77	+1.09	+0.20
0/100/0	U	+0.40	-0.34	-1.14	-0.98	+1.09	+0.36	+0.57	+0.18	-0.54	-0.54	+1.09	+0.40
1000	L	+0.49	+0.76	-1.16	-0.94	+1.01	+0.37	+0.71	+0.24	-0.71	-0.42	+0.83	+0.42
0/100/0	U	+0.26	-0.12	-1.34	-0.94	+1.00	+0.39	+0.28	+0.30	-0.68	-0.43	+0.75	+0.34
2000	L	+0.62	+0.29	-0.70	-0.69	+0.88	+0.95	+0.40	+0.34	-0.60	-0.32	+1.19	+1.06
2/20/78	U	+0.66	+0.30	-1.14	-1.16	+0.99	+0.03	+0.72	+0.34	-0.94	-0.65	+0.75	+0.79
1000	L	+0.30	+0.23	-1.04	-0.96	+1.07	+0.83	+0.46	+0.28	-0.71	-0.39	+0.96	+0.40
2/20/78	U	+0.47	0.00	-1.43	-1.04	+0.65	+0.13	+0.54	+0.48	-0.55	-0.42	+1.43	+0.59
2000	L	+0.22	+0.31	-1.34	-1.08	+0.73	+0.84	+0.49	+0.48	-0.50	-0.39	+0.88	+0.33
15/52/33	U	+0.58	+0.56	-1.22	-0.94	+1.01	+0.67	+0.62	+0.33	-1.00	-0.44	+0.77	+0.69
1000	L	+0.48	+0.41	-1.30	-1.14	+1.38	+0.73	+0.24	+0.42	-0.58	-0.30	+0.95	+0.13
15/52/33	U	+0.14	+0.08	-0.96	-0.78	-0.21	+0.23	+0.20	+0.25	-0.48	-0.48	+0.87	+0.09
2000	L	+0.32	+0.10	-1.36	-1.14	+0.85	+0.72	+0.48	+0.25	-0.38	-0.32	+0.54	+0.49
15/52/33	U	+0.50	+0.17	-0.53	-0.18	+0.51	+0.45	+0.56	+0.44	-0.31	+0.05	+1.03	+0.53
3000	L	+0.36	+0.48	-1.03	-1.02	+0.65	+0.47	+0.70	+0.50	-0.26	-0.06	+0.44	+0.18
30/0/70	U	+0.38	+0.50	-0.81	-0.38	+1.03	+0.62	+0.54	+0.39	-0.57	-0.85	+1.11	+0.79
1000	L	+0.50	+0.49	-1.58	-1.26	+0.95	+0.65	+0.95	+0.62	-0.70	-0.62	+1.37	+0.69
30/0/70	U	-0.08	-0.20	-1.32	-0.84	+0.60	-0.25	+0.20	+0.15	-0.98	-0.40	+0.76	+0.66
2000	L	+0.54	+0.50	-1.36	-1.39	+1.39	+1.04	+0.36	+0.30	-1.00	-0.82	+1.14	+0.19

TABLE III. 129

THIRST PROVOKING PROPERTIES OF DIFFERENT REGIMENS*

Regimen	Osmotic Load Rank	Hard Work Δ, ml	Hard Work Rank	Light Work Δ, ml	Light Work Rank
ST 0	7	370	10	810	5
0/100/0 1000	9	770	8	50	10
0/100/0 2000	10	510	9	430	8
2/20/78 1000	6	790	7	960	3
2/20/78 2000	5	1170	4	2273	1
15/52/33 1000	8	1090	5	370	9
15/52/33 2000	3	810	6	450	7
N 3000	2	1240	2	890	4
30/0/70 1000	4	1320	1	660	6
30/0/70 2000	1	1200	3	1370	2

*Defined as (Water Intake, EXP II U - Water Intake, EXP II L).

TABLE III. 130

WATER DEFICIT CORRELATED WITH CALORIES AND OSMOTIC LOAD IN SECOND WEEK OF EXPERIMENTAL PERIOD

Regimen	Osmotic Load Rank	Hard Work Water Balance Exp II liters/day	Hard Work Rank	Light Work Water Balance Exp II liters/day	Light Work Rank
ST 0	7	-1.18	3	-0.77	2
0/100/0 1000	9	-0.94	9	-0.42	4
0/100/0 2000	10	-0.69	10	-0.32	8
2/20/78 1000	6	-0.96	8	-0.39	6
2/20/78 2000	5	-1.08	6	-0.39	5
15/52/33 1000	8	-1.14	5	-0.30	9
15/52/33 2000	3	-1.14	4	-0.32	7
15/52/33 3000	2	-1.02	7	-0.06	10
30/0/70 1000	4	-1.26	2	-0.62	3
30/0/70 2000	1	-1.39	1	-0.82	1

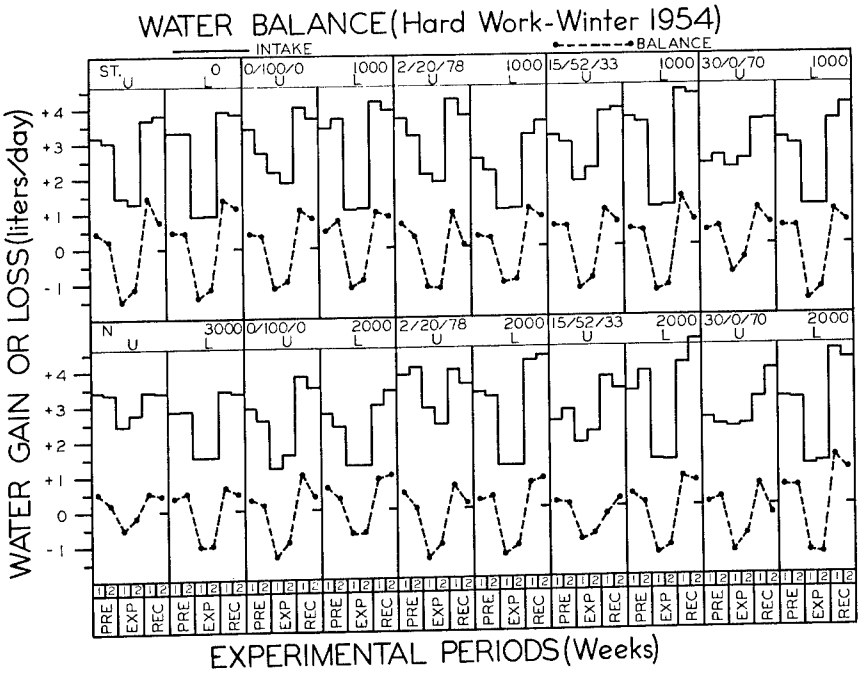

FIGURE III. 39. WATER BALANCE (HARD WORK), WINTER, 1954.

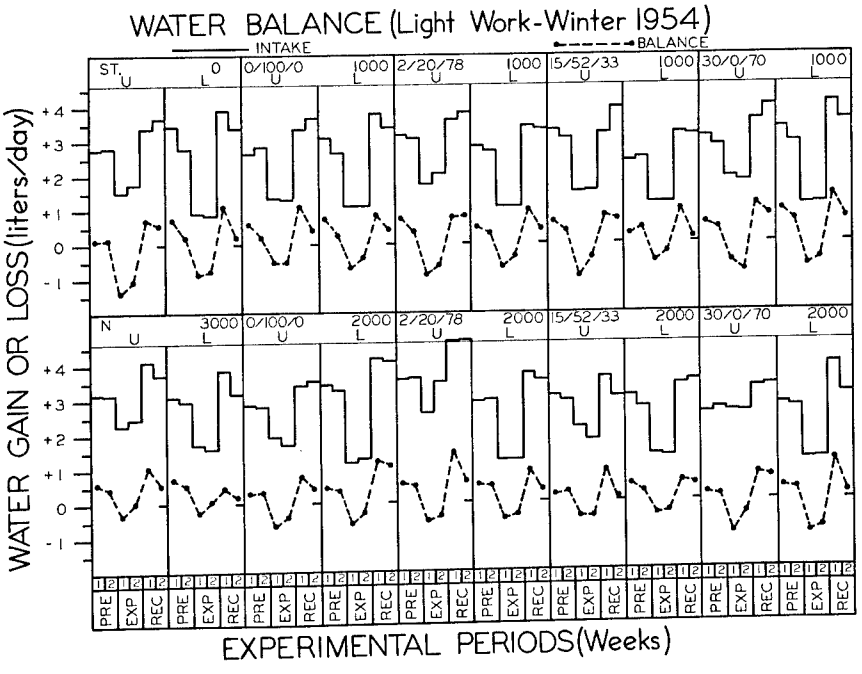

FIGURE III. 40. WATER BALANCE (LIGHT WORK), WINTER, 1954.

3. Nitrogen Balance

Pre-Period. During the two weeks of pre-period, nitrogen intake for all groups ranged between 15 and 20 gm N per day (Table III. 131); this is a usual figure for normal diets. Nitrogen excretion in the urine averaged close to 14 gm N per day in both weeks, and fecal nitrogen excretion was 2 to 3 gm N per day (Table III. 132); these figures are very similar to those of the temperate study of 1953, and are perfectly normal. In P II, urinary nitrogen tended to be a little higher than in P I, and fecal nitrogen a little lower. Pre-period nitrogen balances tended to be slightly positive, as one would expect in this population of young men, many still growing (Table III. 135).

Experimental Period. Work load had no effect on nitrogen balance, and hence can be neglected in the discussion of the experimental period (Figures III. 41 and 42; Tables III. 133, 134, and 135). This finding is consistent with the results of others for this degree of work, which was about 700 Cal/day of work production (increment of calorie expenditure of hard work groups over light work groups); tissue wastage does not occur with this amount of work.

On the other hand, caloric intake had a profound effect on nitrogen balance, as did nitrogen intake per se (Figure III. 43). All subjects tended to be in negative balance, with only a slight tendency toward positivity in EXP II. Scrutiny of the figures, especially Figure III. 43, permits the following conclusions:

a) Work load had no effect on nitrogen balance in any given regimen.

b) Limitation of water had no consistent effect upon nitrogen balance in any given regimen. Hence, the further discussion will omit reference to water intake.

c) Positive balance was achieved only with caloric intakes of 2000 or more, and nitrogen intakes of 16 gm or more.

d) At any given nitrogen intake, addition of calories alleviated the negative nitrogen balance. Good examples of this are seen at zero nitrogen intake, with 0, 1000 and 2000 Cal; and at 11.5 gm N with 1000 and 2000 Cal. This is the well known phenomenon of "nitrogen sparing" by calories.

e) At intakes of 1000 Cal, addition of nitrogen up to 12 gm had little if any effect on the negativity of the nitrogen balance.

f) At 2000 Cal intakes, addition of 2 gm N had no effect on nitrogen balance; addition of 10 gm N more did alleviate the negativity somewhat; and addition of 12 gm N more had little if any further effect. These findings confirm and extend those of the temperate study of 1953.

g) Replacement of carbohydrate isocalorically by fat had no effect upon the nitrogen balance. This finding does not confirm for the human, reports by Hoover and Swanson (1950), Fox, Yang, and Swanson (1952) and Fox and Swanson (1954) that isocaloric replacement of fat with carbohydrate has a nitrogen sparing effect in the protein depleted, calorically undernourished rat. It is interesting to note that Calloway and Spector (1954) failed to confirm Swanson's findings in a carefully controlled study of the rat.

h) In only 25 of the 40 pairs of subjects, there was a slight decrease of negativity in EXP II as compared with EXP I. Thus, there was no convincing evidence of adaptation to these low calorie-low nitrogen regimens so far as

nitrogen balance was concerned.

Our general conclusion is that the hypothesis presented in 1953 for temperate weather holds for cold weather (Johnson et al., 1954). There is a caloric intake below which addition of nitrogen in the diet has no beneficial effect upon nitrogen balance. Thus, we do not confirm Schwimmer, McGavack et al., 1948, 1952-53 on this point, but do confirm Quinn et al. (1954a and b).

Recovery Period. Concomitant with a very large food intake, there was a rebound in nitrogen balance, the greatest positive balances being observed in REC II. At this time, these subjects were laying down from 60 to 100 gm of protein a day, at a time when their body weights were changing very little. Even in two weeks they had not made up completely the nitrogen deficit incurred in the two weeks of deprivation.

TABLE III. 131

NITROGEN INTAKE
(gm/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	18.6	18.3	0.0	0.0	25.4	31.6	17.7	18.2	0.0	0.0	23.6	35.5
	L	19.1	18.8	0.0	0.0	26.8	37.2	18.3	16.4	0.0	0.0	24.8	31.5
0/100/0	U	19.3	15.0	0.0	0.0	27.3	38.8	19.8	19.8	0.0	0.0	24.3	35.0
1000	L	20.2	20.8	0.0	0.0	24.9	30.6	14.8	13.6	0.0	0.0	22.3	33.5
0/100/0	U	18.8	17.1	0.0	0.0	27.6	38.8	17.2	15.2	0.0	0.0	22.9	32.0
2000	L	19.2	15.7	0.0	0.0	19.9	28.3	18.8	19.8	0.0	0.0	23.7	31.5
2/20/78	U	22.4	19.8	1.3	1.3	27.0	40.1	10.4	17.0	1.2	1.3	24.7	36.3
1000	L	14.2	13.6	1.3	1.3	20.5	38.8	18.5	16.6	1.3	1.3	22.7	32.7
2/20/78	U	22.2	21.4	2.2	2.2	25.7	30.7	15.1	21.0	2.1	2.2	27.9	38.0
2000	L	20.0	20.1	2.2	2.2	23.9	36.3	19.2	20.0	2.2	2.2	25.1	33.9
15/52/33	U	19.2	15.5	5.6	5.6	28.0	38.5	19.6	19.4	5.6	5.6	24.3	40.5
1000	L	19.9	18.4	5.6	5.6	23.8	32.4	17.9	17.6	5.6	5.6	22.5	28.1
15/52/33	U	13.7	14.4	11.4	11.4	23.1	34.9	18.4	19.5	11.4	11.4	22.5	28.7
2000	L	17.4	21.8	11.4	11.4	22.8	34.5	16.6	15.2	11.4	11.4	18.0	29.1
15/52/33	U	21.0	18.2	16.6	16.6	20.3	29.5	20.0	19.5	17.0	16.6	27.9	35.5
3000	L	19.9	21.2	16.6	16.6	20.1	28.6	20.0	20.0	16.6	16.6	22.8	28.3
30/0/70	U	11.6	15.0	11.8	12.0	25.0	39.4	21.9	19.2	11.4	12.2	26.5	37.8
1000	L	19.8	18.0	12.0	12.0	22.9	34.9	18.0	17.4	12.0	12.5	23.1	32.7
30/0/70	U	17.0	15.4	23.2	23.8	20.9	31.2	16.0	16.4	23.0	23.5	24.3	30.5
2000	L	18.8	20.2	18.4	23.8	26.5	40.2	16.2	16.5	23.8	22.4	24.3	29.7

TABLE III. 132

PRE-PERIOD DATA ON NITROGEN OUTPUT
URINE AND FECES

Groups of Subjects	P I Mean	P I Range	P II Mean	P II Range
		Urinary N, gm/day		
Flight 1	12.9	7.5-17.8	13.7	9.3-18.3
Flight 2	13.6	9.5-16.6	14.1	8.5-18.5
Flight 3	13.6	9.7-16.7	14.5	10.4-18.1
Flight 4	13.8	11.3-17.5	14.4	10.7-18.1
		Fecal N, gm/day		
Flight 1	3.0	1.0-5.3	2.4	0.7-4.7
Flight 2	3.0	1.1-4.5	2.3	0.5-3.6
Flight 3	2.8	0.9-5.2	2.0	0.6-3.4
Flight 4	2.4	0.7-4.4	1.8	0.7-3.4

TABLE III. 133

URINARY NITROGEN
(gm/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	12.4	14.5	12.0	8.5	12.9	18.9	13.8	16.0	10.9	9.8	14.8	18.3
	L	13.0	13.6	12.9	11.3	11.5	17.1	14.0	14.5	11.9	11.2	16.3	18.0
0/100/0	U	12.5	16.0	8.4	5.7	15.4	21.3	14.0	16.2	7.2	5.0	12.6	19.5
1000	L	12.8	13.8	8.2	6.7	11.6	14.6	12.4	13.2	7.4	6.6	12.4	16.2
0/100/0	U	16.0	14.7	7.5	5.3	13.4	22.0	12.2	12.2	6.0	4.0	10.6	17.0
2000	L	12.5	12.6	4.9	5.0	11.6	15.5	14.8	15.4	6.2	4.2	12.2	17.2
2/20/78	U	12.7	15.6	11.4	10.6	16.6	22.8	12.4	12.6	8.3	6.8	14.1	17.2
1000	L	11.8	11.2	13.0	10.7	15.0	18.8	13.4	14.0	11.5	7.9	12.9	18.4
2/20/78	U	14.4	15.9	10.9	7.8	15.4	18.4	14.1	14.2	9.2	7.1	11.2	19.4
2000	L	14.3	15.2	9.6	7.0	15.5	20.1	15.3	16.6	9.0	7.4	14.2	17.9
15/52/33	U	13.7	12.7	11.1	11.3	15.6	13.0	13.4	14.0	10.0	9.6	14.4	22.2
1000	L	15.4	14.5	11.2	12.2	13.2	17.2	14.7	14.2	10.8	9.2	12.4	17.4
15/52/33	U	11.7	11.4	13.6	13.3	14.4	20.4	14.3	15.2	12.0	11.6	14.5	16.4
2000	L	14.1	16.3	13.2	13.2	13.1	17.9	13.5	13.2	13.2	14.6	12.6	15.2
15/52/33	U	13.0	13.4	14.0	13.8	12.8	13.2	15.0	15.7	15.8	16.0	18.0	21.6
3000	L	14.8	15.2	17.7	17.7	14.8	15.4	14.6	17.4	16.6	13.4	12.8	16.8
30/0/70	U	9.9	11.0	13.0	12.5	14.9	18.6	14.0	16.0	18.9	19.0	13.4	19.8
1000	L	13.1	12.6	19.6	18.2	14.0	17.8	13.7	12.7	18.1	19.6	13.4	15.4
30/0/70	U	12.8	12.8	22.2	22.4	12.3	16.9	12.2	12.0	23.2	25.8	15.2	17.0
2000	L	14.7	17.1	21.2	26.5	16.6	21.4	12.0	13.0	25.4	25.6	15.2	15.8

TABLE III. 134

FECAL NITROGEN
(gm/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	3.7	3.4	0.6	0.4	6.6	3.0	2.0	1.4	0.5	0.8	2.4	2.9
	L	3.2	2.5	0.3	0.3	4.6	2.5	1.9	1.8	0.3	0.3	3.4	2.5
0/100/0	U	2.6	1.9	0.6	1.4	3.9	3.6	2.4	2.0	0.4	0.6	2.4	2.1
1000	L	4.4	3.1	0.3	0.3	4.9	2.9	1.6	1.8	0.5	0.5	2.2	2.2
0/100/0	U	2.7	0.7	0.4	0.8	4.8	2.7	3.1	2.8	0.6	0.6	3.1	3.0
2000	L	3.4	2.6	0.8	0.8	4.4	3.2	3.2	2.0	2.4	0.6	1.8	2.3
2/20/78	U	3.5	2.8	1.0	0.8	4.6	2.0	2.0	1.8	0.8	0.6	4.0	2.4
1000	L	1.8	0.6	0.4	0.6	2.4	2.1	3.2	1.2	0.6	0.6	2.5	1.4
2/20/78	U	4.4	3.5	1.0	1.2	5.4	2.6	3.7	1.6	2.6	1.0	6.9	3.4
2000	L	2.8	2.6	0.6	0.6	5.6	2.7	2.3	1.6	0.6	0.6	1.1	1.5
15/52/33	U	3.2	1.9	1.2	1.1	4.7	3.2	3.4	2.0	1.5	1.2	4.4	3.0
1000	L	2.4	1.6	0.4	0.5	2.2	2.0	2.4	1.9	0.6	0.6	2.6	1.6
15/52/33	U	1.4	1.5	0.8	0.8	4.9	2.3	2.9	2.4	2.3	1.0	2.0	2.4
2000	L	3.6	1.9	1.0	1.0	3.7	2.9	2.2	2.5	1.0	1.0	2.6	2.1
15/52/33	U	4.0	3.2	3.2	2.4	3.8	2.8	2.2	2.8	2.2	1.8	6.6	2.2
3000	L	2.8	2.9	1.8	2.4	3.1	3.4	1.6	1.8	1.8	1.8	2.1	1.3
30/0/70	U	2.1	2.1	1.2	1.4	4.4	3.6	4.2	1.8	0.7	1.6	2.8	2.2
1000	L	3.2	2.4	0.6	0.6	5.0	2.6	3.8	2.0	0.6	0.6	3.3	3.6
30/0/70	U	1.8	2.0	1.0	0.5	3.0	1.9	2.6	2.0	1.2	1.5	3.7	2.2
2000	L	2.0	2.4	1.4	0.8	4.7	3.1	2.6	1.6	1.1	1.1	1.2	2.6

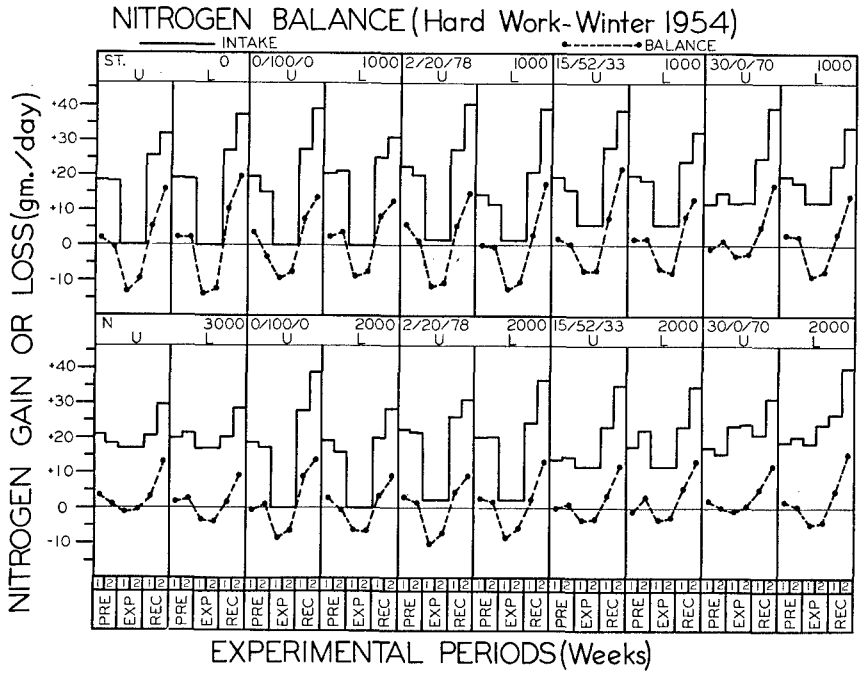

FIGURE III. 41

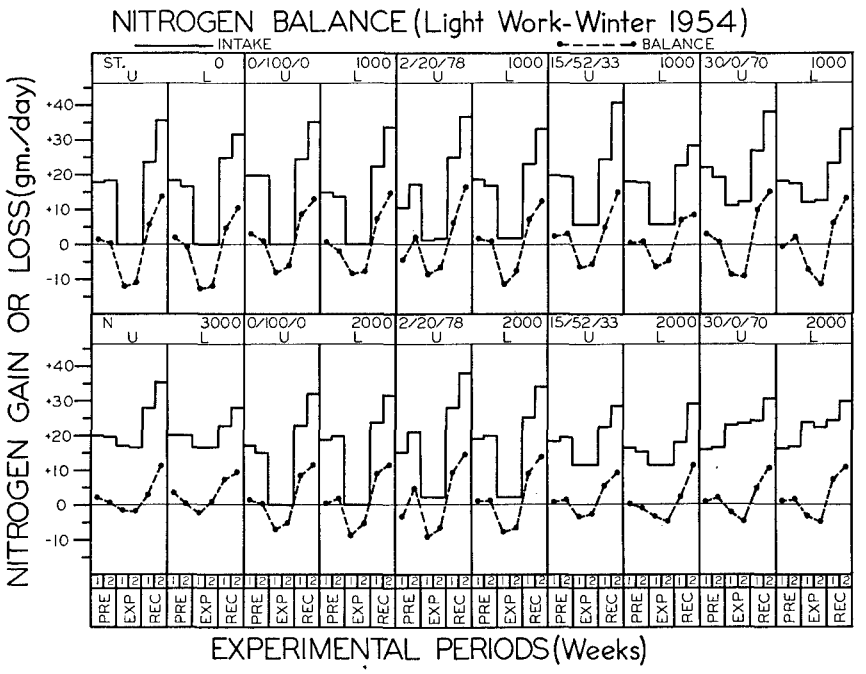

FIGURE III. 42

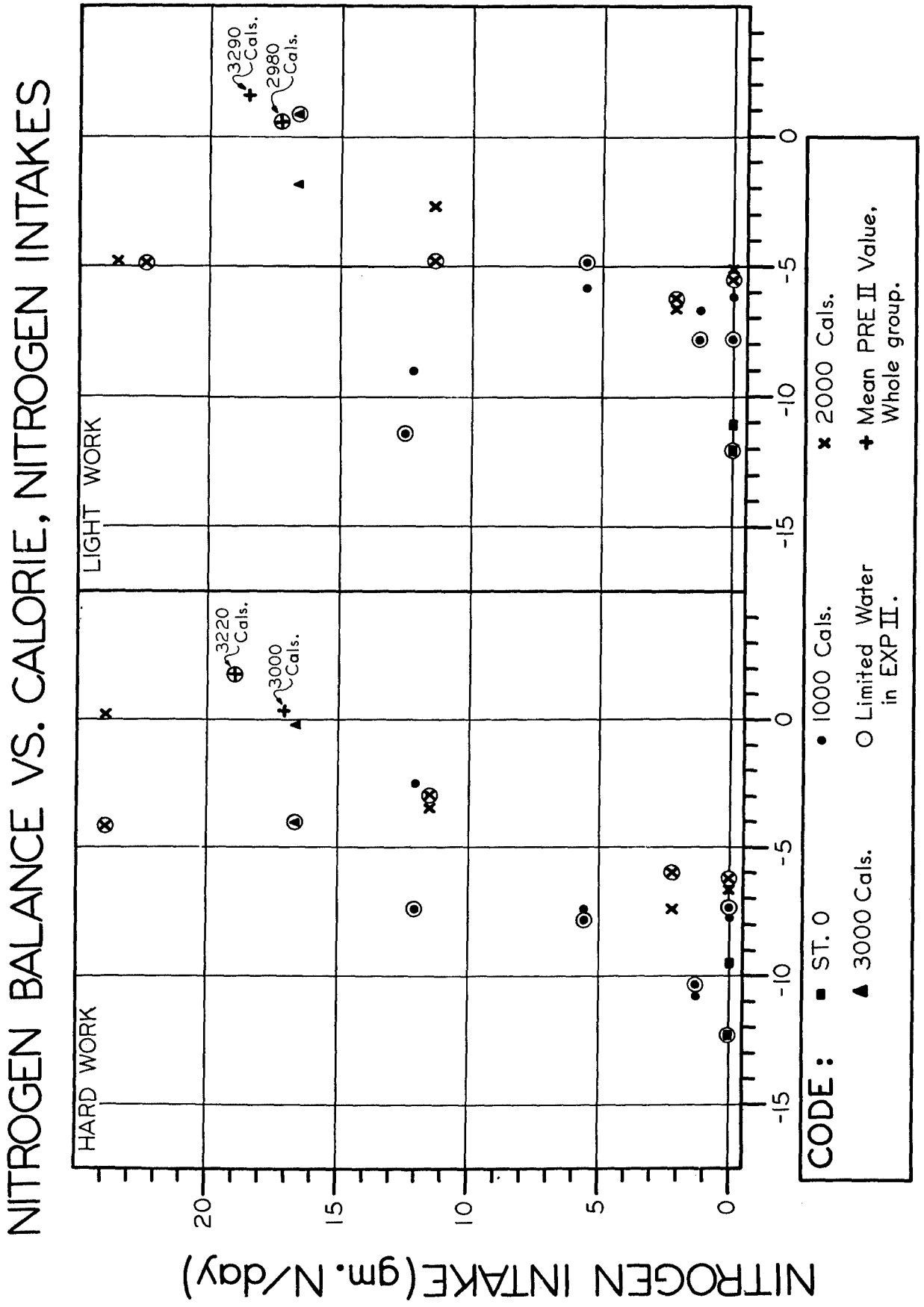

FIGURE III. 43. NITROGEN BALANCE VS. CALORIE AND NITROGEN INTAKES.

TABLE III. 135

NITROGEN BALANCE
(gm/day)

Experimental Regimen		Hard Work Pre I	Hard Work Pre II	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre I	Light Work Pre II	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	+1.9	-0.1	-13.2	- 9.5	+ 5.1	+15.9	+1.3	+0.2	-12.0	-11.1	+5.8	+13.7
	L	+2.3	+2.1	-13.7	-12.3	+10.1	+19.4	+1.8	-0.5	-12.8	-12.0	+4.5	+10.3
0/100/0	U	+3.6	-3.4	- 9.5	- 7.6	+ 7.3	+13.3	+2.8	+1.0	- 8.2	- 6.2	+8.6	+12.8
1000	L	+2.4	+3.6	- 9.1	- 7.6	+ 7.8	+12.4	+0.3	-2.0	- 8.5	- 7.8	+7.2	+14.6
0/100/0	U	-0.5	+1.1	- 8.5	- 6.6	+ 8.8	+13.5	+1.3	0	- 7.2	- 5.2	+8.6	+11.5
2000	L	+2.6	-0.1	- 6.3	- 6.5	+ 3.2	+ 9.0	+0.3	+1.8	- 9.2	- 5.4	+9.0	+11.4
2/20/78	U	+5.6	+0.8	-11.8	-10.7	+ 5.2	+14.6	-4.6	+2.1	- 8.6	- 6.7	+6.0	+16.2
1000	L	0	-0.4	-12.8	-10.6	+ 2.6	+17.3	+1.4	+0.8	-11.4	- 7.8	+6.8	+12.3
2/20/78	U	+2.8	+1.4	-10.3	- 7.4	+ 4.4	+ 9.0	-3.3	+4.8	- 9.2	- 6.6	+9.2	+14.5
2000	L	+2.4	+1.6	- 8.6	- 6.0	+ 2.2	+12.9	+1.0	+1.2	- 8.0	- 6.4	+9.2	+13.8
15/52/33	U	+1.7	+0.3	- 7.4	- 7.4	+ 7.5	+21.6	+2.2	+2.9	- 6.5	- 5.8	+4.9	+14.8
1000	L	+1.5	+1.6	- 6.6	- 7.8	+ 7.8	+12.7	+0.2	+0.9	- 6.4	- 4.8	+6.8	+ 8.6
15/52/33	U	0	+1.0	- 3.6	- 3.4	+ 3.2	+11.6	+0.6	+1.4	- 3.4	- 2.7	+5.4	+ 9.3
2000	L	-1.0	+3.0	- 3.4	- 3.0	+ 5.4	+13.1	+0.3	-1.1	- 3.4	- 4.8	+2.3	+11.2
15/52/33	U	+3.5	+1.0	- 1.2	- 0.2	+ 3.1	+13.0	+2.2	+0.4	- 1.6	- 1.8	+2.8	+11.2
3000	L	+1.6	+2.5	+ 3.4	- 4.0	+ 1.6	+ 9.2	+3.6	+0.2	- 2.3	+ 0.8	+7.4	+ 9.6
30/0/70	U	-1.0	+1.2	- 3.0	- 2.5	+ 5.1	+17.0	+3.0	+0.8	- 8.8	- 9.0	+9.8	+15.0
1000	L	+2.9	+2.4	- 8.7	- 7.4	+ 3.3	+14.0	-0.2	+2.1	- 7.4	-11.4	+5.8	+13.0
30/0/70	U	+1.8	+0.1	- 0.6	+ 0.2	+ 5.1	+11.8	+0.6	+1.9	- 2.2	- 4.8	+4.8	+10.6
2000	L	+1.6	+0.2	- 4.8	- 4.2	+ 4.7	+15.1	+1.0	+1.4	- 3.4	- 4.9	+7.2	+10.8

4. Chloride Balance

Pre-Period. Urinary chloride averaged around 300 mEq per day in both pre-period weeks (Table III. 136); the absolute range was 148-419 mEq. These data are normal for men subsisting on diets high in salt (Table III. 137). The urinary output of chloride in Flight 4 decreased sharply in P II, but the other three flights remained relatively constant. As is usual, there was considerable variability from man to man (Table III. 138).

Experimental Period. In EXP I there was an abrupt drop in urinary chloride, together with a negative balance, in all groups of subjects. These changes were concomitant with a diminution in chloride intake in all groups in EXP I (Figures III. 44 and III. 45; Tables III. 138 and 139). During EXP II there was a further diminution in most subjects, with a decrease in negative balance in 37 of the 40 regimens under study. However, only one regimen permitted both the hard and the light work pairs to achieve positive balance: 2/20/78 2000, with a chloride intake of 155 mEq, which was the highest of all the regimens. The general striking finding was that in both hard and light work, in all other regimens, with or without limitation of water, balance remained negative in EXP II. This did not happen in the temperate study of 1953, where balance was achieved even at low chloride intakes, in EXP II.

Examination of the tables and charts permits the following conclusions:

a) Calorie intake per se had no effect upon chloride balance, if one inspects regimens of different caloric intakes and protein intakes, but with different chloride intakes.

b) Chloride intake per se did have an influence. Calorie intake and protein intake being constant, increase of chloride intake assisted toward a less negative balance.

c) Work load had no consistent effect, in spite of loss of chloride in the sweat of the hard work groups. In the 20 paired regimens, calorie intake, chloride intake, and protein intake all being the same, the hard work pairs had a greater negative balance in EXP II in only 9 cases, the light work groups being more negative in 11.

d) Protein intake had a profound effect upon chloride balance (Figure III. 46). If chloride intake as abscissa is plotted against chloride balance as ordinate, and the regimens are identified as those providing less than 10 gm N per day (ST 0, 0/100/0 1000, 0/100/0 2000, 2/20/78 1000, 2/20/78 2000, 15/52/33 1000), those providing 10-20 gm N (15/52/33 2000, 15/52/33 3000, 30/0/70 1000) and those providing more than 20 gm N (30/0/70 2000), for all four major groups the same results were obtained. At the same chloride intake, addition of nitrogen to the regimen made the chloride balance more negative. In low nitrogen regimens, increasing chloride intakes resulted in closer approaches to positive balance, which was finally achieved with intakes around 150 mEq. With larger intakes of protein, addition of chloride helped the negative balance only in the light work, limited water group, but not in the other three. As a rough approximation, addition of 10 gm N per day made the balance more negative by about 40 mEq per day at any level of chloride intake.

What explanation can be offered for the fact that, even taking protein into account, almost all subjects in all regimens remained in negative chloride

balance throughout the experimental periods? We postulate that there was an environmental factor, common to all of them. This might have been temperature alone, or it might have been the sum total of field conditions. We know that almost all subjects were in negative water balance, were losing weight, and were in negative nitrogen balance. It is therefore likely that they were losing extracellular fluid continuously, and with it, chloride.

Recovery. There being no data on chloride content of the foods eaten in REC II, only balances for REC I were calculated. During the latter week, all subjects went into strong positive chloride balance, thus replacing the deficit incurred in the two experimental weeks. In REC II, urinary chloride exceeded that excreted in the pre-periods; presumably during this week, chloride balance remained strongly positive.

TABLE III. 136

PRE-PERIOD DATA ON URINARY CHLORIDE
(mEq Cl/day)

	P I		P II	
Flight	Mean	Range	Mean	Range
1	288	117-365	259	168-385
2	278	152-339	279	162-376
3	307	148-419	317	232-396
4	323	242-368	246	193-347

TABLE III. 137-

CHLORIDE INTAKE
(mEq/day)

Experimental Regimen		Hard Work					Light Work				
		Pre		Exp		Rec	Pre		Exp		Rec
		I	II	I	II	I	I	II	I	II	I
ST 0	U	344	320	0	0	437	358	342	0	0	416
	L	347	322	0	0	407	377	313	0	0	443
0/100/0	U	361	292	0	0	493	362	344	0	0	435
1000	L	374	361	0	0	434	321	281	0	0	417
0/100/0	U	353	319	0	0	479	330	273	0	0	411
2000	L	359	277	0	0	365	357	313	0	0	429
2/20/78	U	433	341	79	79	468	200	300	79	79	372
1000	L	278	249	79	79	361	341	297	79	79	402
2/20/78	U	411	378	155	155	431	306	371	155	155	491
2000	L	378	357	155	155	403	367	362	155	155	449
15/52/33	U	365	275	37	37	475	411	367	37	37	451
1000	L	362	327	37	37	411	334	301	37	37	381
15/52/33	U	287	285	90	90	443	379	361	90	90	419
2000	L	343	392	90	90	377	323	263	90	90	314
15/52/33	U	402	313	110	110	363	359	325	110	110	461
3000	L	366	358	110	110	375	359	316	110	110	401
30/0/70	U	213	247	1	1	429	393	334	1	1	460
1000	L	357	297	1	1	406	340	319	1	1	419
30/0/70	U	307	225	2	2	359	295	303	2	2	402
2000	L	353	349	2	2	459	337	307	2	2	457

TABLE III. 138

URINARY CHLORIDE
(mEq Cl/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	281	277	72	15	263	433	331	328	64	30	273	417
	L	268	314	75	14	246	406	356	301	68	28	309	463
0/100/0	U	311	260	79	0	356	394	319	353	52	29	267	424
1000	L	285	302	54	4	266	398	272	267	56	28	254	342
0/100/0	U	312	254	65	5	330	392	292	257	54	30	282	360
2000	L	276	230	51	2	250	360	336	298	54	31	307	359
2/20/78	U	312	309	101	90	338	458	160	278	111	100	340	386
1000	L	220	214	104	102	288	426	328	274	122	94	314	374
2/20/78	U	320	306	167	148	393	266	286	352	152	155	324	439
2000	L	300	281	154	125	193	358	332	316	154	165	320	366
15/52/33	U	276	237	78	38	316	348	364	342	75	67	298	412
1000	L	287	277	73	26	186	366	334	302	104	60	263	320
15/52/33	U	316	242	154	129	307	274	349	335	130	139	298	307
2000	L	278	269	154	120	274	366	291	251	155	144	239	297
15/52/33	U	312	262	159	144	279	258	333	312	200	181	362	428
3000	L	284	302	178	146	328	306	317	333	184	137	286	290
30/0/70	U	195	202	79	14	358	394	358	324	90	72	295	437
1000	L	288	251	82	36	290	390	320	264	85	65	283	342
30/0/70	U	244	220	121	78	232	319	274	285	132	114	310	345
2000	L	306	317	94	80	354	400	328	280	128	104	342	320

TABLE III. 139

CHLORIDE BALANCE
(mEq/day)

Experimental Regimen		Hard Work					Light Work				
		Pre		Exp		Rec	Pre		Exp		Rec
		I	II	I	II	I	I	II	I	II	I
ST 0	U	+124	+86	- 94	- 40	+199	+27	+14	- 64	- 30	+143
	L	+160	+17	- 99	- 39	+161	+21	+12	- 68	- 28	+134
0/100/0	U	+ 50	+37	-104	- 25	+137	+43	- 9	- 51	- 29	+167
1000	L	+ 89	+59	- 79	- 29	+168	+49	+13	- 56	- 28	+163
0/100/0	U	+ 40	+90	- 90	- 30	+150	+38	+16	- 54	- 29	+179
2000	L	+ 63	+46	- 76	- 28	+116	+21	+15	- 54	- 31	+121
2/20/78	U	+120	+32	- 45	- 34	+129	+41	+19	- 35	- 21	+ 69
1000	L	+ 57	+37	- 50	- 47	+ 73	+13	+23	- 43	- 15	+ 88
2/20/78	U	+ 81	+37	- 37	- 17	+ 39	+20	+19	- 11	0	+167
2000	L	+ 77	+76	- 24	+ 5	+210	+34	+31	+ 1	- 10	+123
15/52/33	U	+ 90	+38	- 66	- 27	+159	+47	+24	- 38	- 30	+157
1000	L	+ 82	+51	- 61	- 14	+225	+ 1	- 1	- 67	- 23	+117
15/52/33	U	- 30	+43	- 89	- 64	+136	+30	+21	- 41	- 49	+121
2000	L	+ 65	+16	- 89	- 51	+103	+32	+12	- 65	- 54	+ 76
15/52/33	U	+ 89	+51	- 74	- 59	+ 83	+27	+13	- 88	- 71	+ 99
3000	L	+ 83	+55	- 93	- 61	+ 47	+43	-17	- 74	- 24	+115
30/0/70	U	+ 18	+44	-103	- 38	+ 70	+36	+11	- 89	- 71	+165
1000	L	+ 66	+45	-106	- 59	+117	+20	+55	- 84	- 64	+136
30/0/70	U	+ 63	+ 4	-144	-101	+128	+21	+18	-129	-113	+ 93
2000	L	+ 47	+33	-118	-103	+103	+ 9	+27	-126	-102	+115

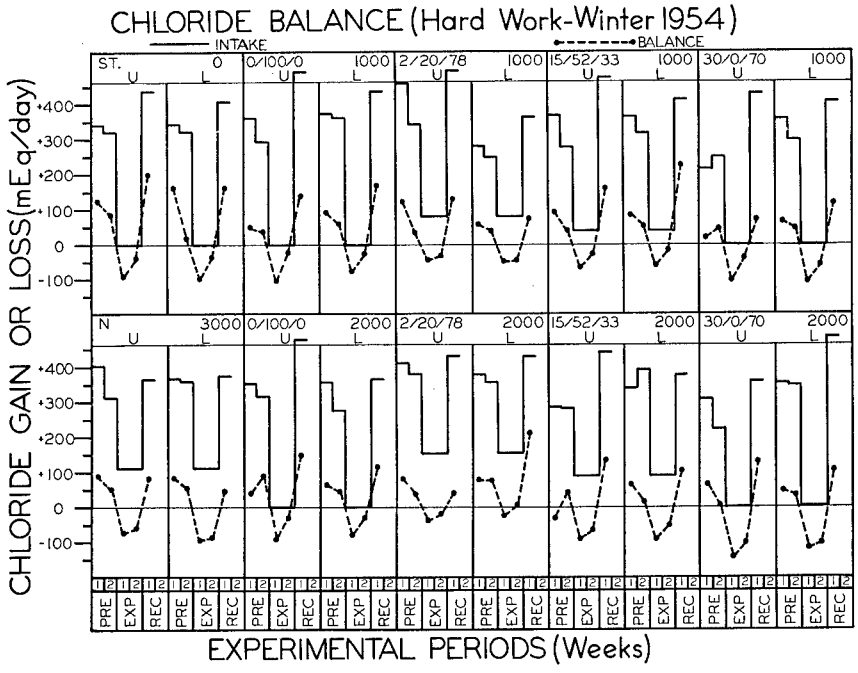

FIGURE III. 44

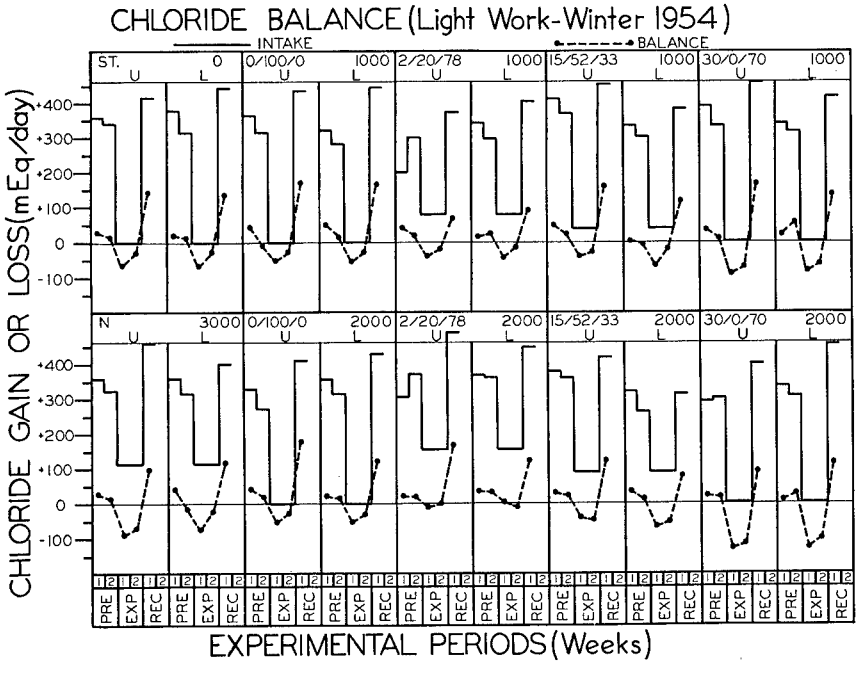

FIGURE III. 45

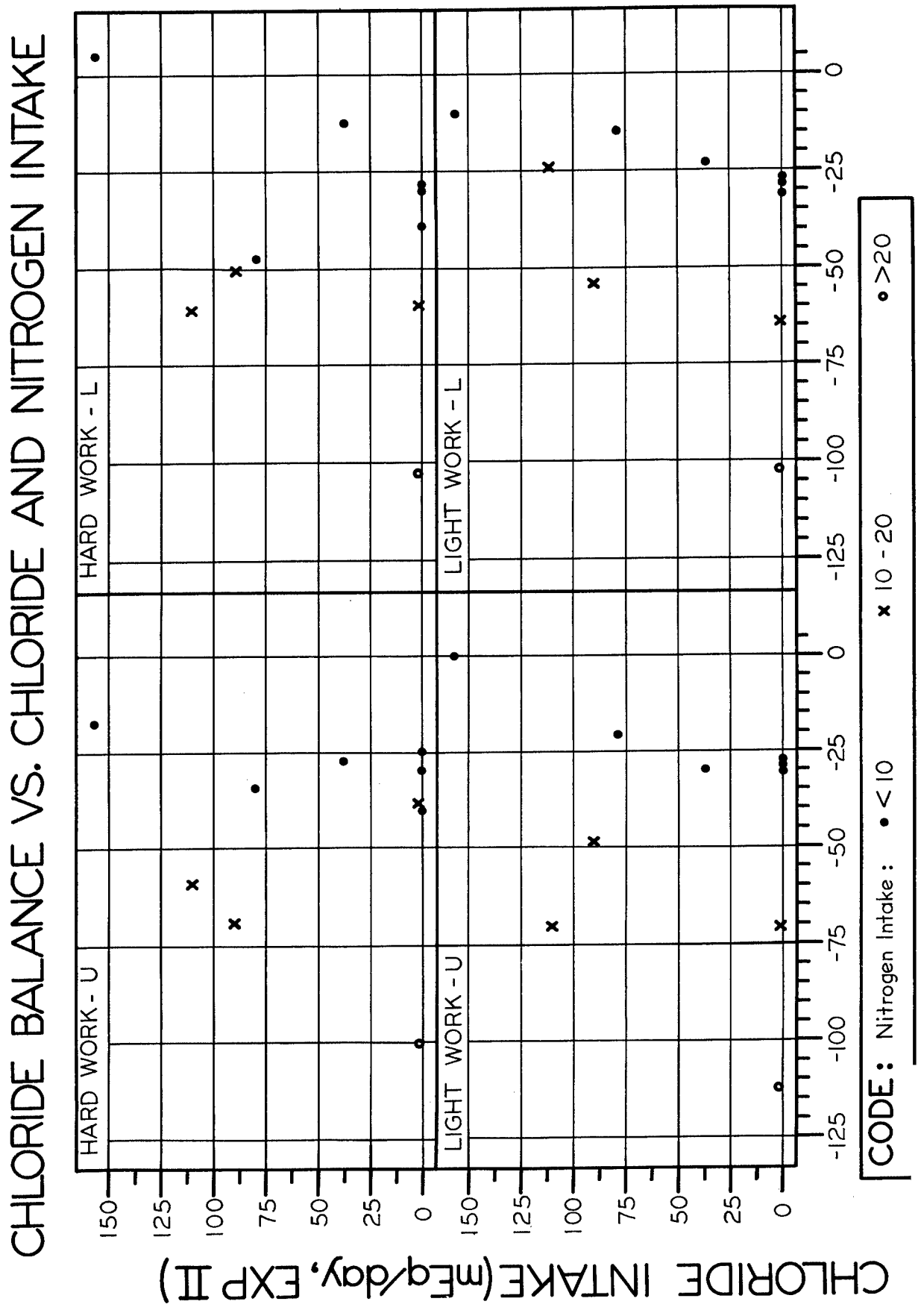

FIGURE III. 46. CHLORIDE BALANCE VS. CHLORIDE AND NITROGEN INTAKES.

5. Sodium Balance

Pre-Period. The urinary excretion of sodium was around 280 mEq/day in the first pre-period week, dropping in three flights to about 270 in the second week; the third flight increased to 302 in the second week (Table III. 140). These urinary figures are normal for a high salt diet (Table III. 141), and also showed the usual wide normal range (100 to 400 mEq/day).

Experimental Period. In all flights there was a precipitate drop in urinary excretion in the first experimental week, followed usually by a further drop in the second week (Table III. 142). The lowest figures in EXP II were found for men on the lowest sodium intake (Table III. 141). Three regimens were extremely low in sodium: ST 0, 0/100/0 1000, and 0/100/0 2000.

Caloric intake in itself had no significant effect on sodium balance (Table III. 143; Figures III. 47 and 48), judging by the data for 0/100/0 1000 and 2000.

Although all subjects tended to become less negative in EXP II, work load did have a specific effect upon sodium balance in almost all paired comparisons, presumably because of the sodium lost in the sweat of the hard work groups. In general, the balances were 10 to 20 mEq less negative for the light work groups than for the hard work groups. In these latter, only intakes of 100 mEq or over produced positive balance; in the light work groups, balance was achieved with intakes of around 60 mEq.

Water intake had little if any effect upon sodium balance. Neither was there any consistent influence of osmotic load. The balance tended to be related directly to the sodium intake, regardless of the nature of the nutrient mixture. In this respect, sodium behaved quite differently from chloride. For chloride, increasing the protein in the diet decreased the chloride balance at a given chloride intake.

Since most of the light work groups were near balance in EXP II (15 of 20 regimens), and several of the hard work groups (10 of 20), we conclude that there was no non-specific influence at work as there appeared to be for chloride; in all groups, except those on a high intake, chloride balance was negative.

Recovery. With the very large food intake in recovery, there was a large increase in urinary sodium excretion, some figures of over 400 mEq being recorded in the second week (Table III. 142). There was no apparent relationship between urinary sodium in recovery, and the particular regimen of the subjects during the experimental period.

Comparison of Results, 1954 vs. 1953. In the temperate study of 1953, analytical difficulties rendered doubtful some of the data for sodium intake. These difficulties were solved, and the foodstuffs have been reanalyzed. The empirical correction factor that was employed in 1953 turned out to be very close to the true value (Table III. 144). Hence, we can now speak with more assurance about the 1953 data. The results were very similar in the 1953

subjects and in the light work groups in 1954. That is, sodium balance could be achieved with very small intakes of sodium.

TABLE III. 140

PRE PERIOD DATA ON URINARY SODIUM AND SODIUM INTAKE
(mEq/day)

Flight	P I Mean	P I Range	P II Mean	P II Range
		Urine		
1	279	101-428	264	175-356
2	286	162-364	274	148-400
3	284	141-400	302	207-396
4	294	222-341	278	178-330
		Intake		
1	337	105-471	284	109-406
2	345	222-403	320	203-388
3	331	177-443	331	234-399
4	346	252-387	305	230-339

TABLE III. 141

SODIUM INTAKE
(mEq/day)

Experimental Regimen		Hard Work					Light Work				
		Pre		Exp		Rec	Pre		Exp		Rec
		I	II	I	II	I	I	II	I	II	I
ST 0	U	335	325	1	1	447	359	331	1	2	420
	L	350	316	1	1	424	366	307	1	1	458
0/100/0	U	360	263	6	6	500	352	341	5	5	434
1000	L	367	361	6	6	444	320	277	5	5	430
0/100/0	U	343	316	9	9	490	322	276	10	10	412
2000	L	340	276	9	9	365	364	308	9	9	436
2/20/78	U	433	343	79	79	492	200	295	77	79	423
1000	L	263	241	78	78	360	349	300	78	78	410
2/20/78	U	412	366	158	157	450	319	374	145	158	508
2000	L	374	343	156	156	413	365	348	156	156	454
15/52/33	U	369	273	62	63	486	360	373	62	62	468
1000	L	355	314	62	62	410	336	305	62	62	386
15/52/33	U	293	285	178	179	428	391	358	178	178	419
2000	L	339	388	178	178	388	320	263	178	178	322
15/52/33	U	397	306	213	213	370	329	323	214	213	458
3000	L	362	359	212	204	379	362	318	212	212	394
30/0/70	U	226	249	55	55	452	378	334	53	56	462
1000	L	344	298	56	55	417	340	314	55	57	420
30/0/70	U	308	244	106	109	372	394	306	106	108	408
2000	L	354	344	84	107	463	338	308	108	102	454

TABLE III. 142

URINARY SODIUM
(mEq/day)

Experimental Regimen		Hard Work Pre I	Hard Work Pre II	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre I	Light Work Pre II	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST O	U	293	305	70	48	300	402	304	310	58	17	302	374
	L	279	272	68	20	240	382	306	285	48	16	332	445
0/100/0	U	316	264	63	18	338	388	290	330	40	15	287	418
1000	L	292	301	36	18	278	394	246	272	49	18	268	324
0/100/0	U	296	260	45	19	343	388	276	237	60	31	278	336
2000	L	272	225	26	13	272	343	315	282	39	21	292	340
2/20/78	U	338	302	98	101	382	401	146	232	110	106	325	343
1000	L	230	208	94	114	287	414	266	255	98	97	305	388
2/20/78	U	320	305	140	168	394	256	259	338	146	195	326	407
2000	L	290	287	148	132	376	353	311	312	154	170	326	366
15/52/33	U	264	184	63	52	324	360	342	347	78	64	302	420
1000	L	292	281	60	52	281	356	308	270	86	69	274	308
15/52/33	U	208	256	146	136	308	268	323	332	148	147	289	290
2000	L	303	274	142	117	285	342	273	244	158	134	242	260
15/52/33	U	311	262	164	152	284	258	326	323	200	176	378	386
3000	L	302	318	378	149	334	274	310	326	174	142	280	278
30/0/70	U	185	199	58	32	323	374	332	296	77	54	278	404
1000	L	296	251	92	48	282	384	290	256	75	74	322	318
30/0/70	U	244	212	127	88	228	306	246	268	114	118	261	304
2000	L	312	330	88	76	350	369	206	278	130	98	325	298

TABLE III. 143

SODIUM BALANCE
(mEq/day)

Experimental Regimen		Hard Work Pre I	Pre II	Exp I	Exp II	Rec I	Light Work Pre I	Pre II	Exp I	Exp II	Rec I
ST 0	U	+ 43	+20	-93	-72	+148	+55	+21	-57	-16	+118
	L	+ 70	+44	-92	-44	+184	+57	+22	-47	-15	+176
0/100/0	U	+ 44	- 2	-82	-38	+161	+61	+12	-36	-10	+146
1000	L	+ 74	+60	-55	-38	+166	+74	+ 5	-44	-13	+161
0/100/0	U	+ 47	+64	-67	-35	+147	+46	+39	-51	-22	+134
2000	L	+ 66	+52	-42	-29	+ 93	+49	+26	-30	-12	+144
2/20/78	U	+ 95	+40	-44	-47	+110	+54	+62	-34	-20	+ 98
1000	L	+ 33	+33	-40	-60	+ 74	+82	+45	-26	-19	+104
2/20/78	U	+ 92	+25	-60	-36	+ 56	+59	+36	+ 1	-37	+182
2000	L	+ 84	+56	-17	- 1	+ 37	+54	+36	+ 3	-14	+128
15/52/33	U	+104	+38	-26	-14	+162	+26	+26	-16	- 2	+165
1000	L	+ 64	+33	-23	-15	+129	+28	+35	-24	- 7	+112
15/52/33	U	+ 86	+30	+ 7	+18	+120	+58	+26	+31	+31	+130
2000	L	+ 36	-12	+10	+36	+104	+46	+20	+20	+44	+ 80
15/52/33	U	+ 86	+44	+24	+36	+ 85	+ 3	+ 2	+14	+37	+ 80
3000	L	+ 60	+41	+10	+30	+ 46	+52	-28	+38	+70	+114
30/0/70	U	+ 40	+50	-28	- 2	+128	+46	+38	-24	+ 2	+184
1000	L	+ 48	+46	-62	-18	+136	+50	+58	-20	-17	+ 98
30/0/70	U	+ 63	+33	-46	- 4	+144	+48	+37	- 8	-10	+148
2000	L	+ 42	+13	-30	+ 6	+113	+31	+30	-22	+ 4	+128

TABLE III. 144

COMPARISON OF SODIUM AND POTASSIUM ANALYSES: FOOD-1954 VS. 1953

Category of Food	Sodium No. of Items*	Sodium Mean % '53/'54	Potassium No. of Items*	Potassium Mean % '53/'54
A. 5-in-1 Components				
Meat products	10	53	11	24
Vegetables	6	71	5	60
Desserts & fruit	4	57	3	87
Soups & beverages	3	71	2	75
Bread & cereals	2	95	2	22
Candies, spreads, misc.	6	72	4	53
B. Components, Other Rations	3	83	3	42
C. Special Supplements	6	86	6	86
Average, all groups		73		51

*Refers to food items of which the sodium or potassium concentration, or both, was greater than 100 mg/100 gm.

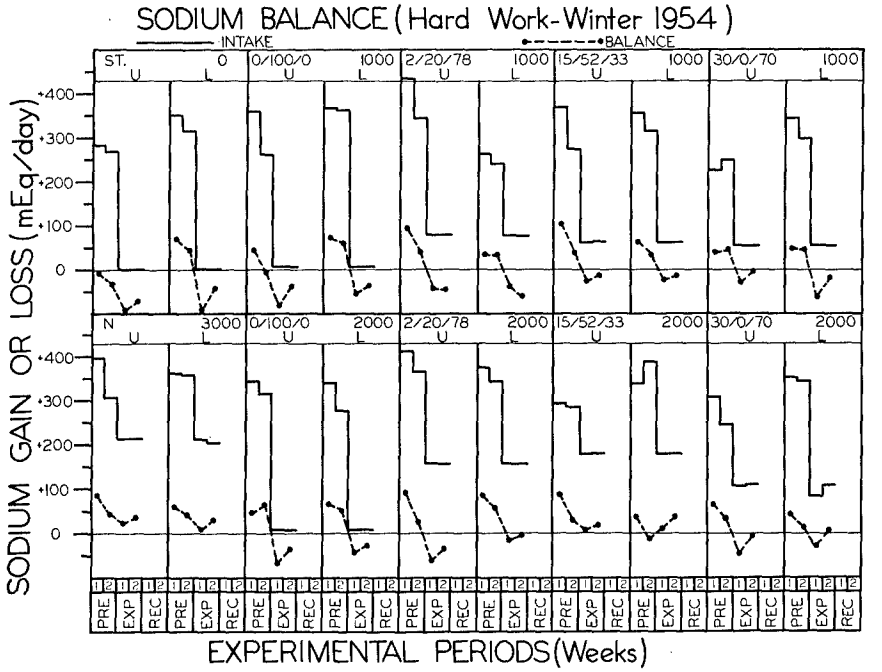

FIGURE III. 47. SODIUM BALANCE (HARD WORK), WINTER, 1954.

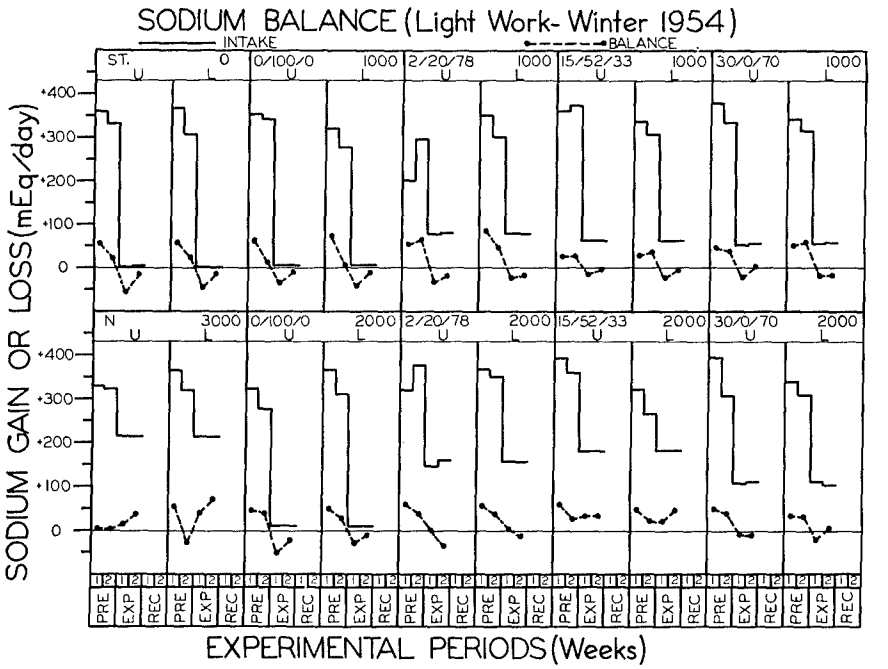

FIGURE III. 48. SODIUM BALANCE (LIGHT WORK), WINTER, 1954.

6. Potassium Balance

Potassium balance was of particular interest in the present study, because this cation is purported to come principally from the cells, and our subjects were exposed to nutritional as well as situational stresses that might be expected to catabolize cells.

Pre-Period. Urinary potassium amounted to about 65 mEq per day in the P I, falling to about 59 in P II (Table III. 145). There was a large variability in both weeks, as is normal. Fecal potassium amounted to about 20% of the urinary, and diminished slightly in P II (Table III. 145). Both urinary and fecal potassium were comparable to those of the subjects of the temperate study of 1953.

Experimental Period. Potassium intake was very low in five diets (ST 0, 0/100/0 1000, 0/100/0 2000, 2/20/78 1000 and 2/20/78 2000); it was intermediate in two (15/52/33 1000 and 30/0/70 2000); and it was fairly high in the other three (15/52/33 2000, 15/52/33 3000 and 30/0/70 2000). No experimental diet could be considered high in potassium (Table III. 146).

Associated with the low and intermediate intakes was a decline in urinary excretion of potassium in ST 0, 0/100/0 1000, 0/100/0 2000, 2/20/78 1000, 2/20/78 2000 and 15/52/33 1000 (Table III. 147). Fecal excretion was low among men on these diets and tended to be low also in all other diets except N 3000 (Table III. 148). Neither for urine nor feces was the second experimental week appreciably different from the first.

The striking feature of the balances was that in none of the forty paired regimens did the subjects achieve positive potassium balance even in EXP II, when equilibrium was to be expected if it were going to happen (Table III. 149; Figures III. 49 and 50). There was a tendency for negativity to be less severe in EXP II (17 of 20 comparisons in hard work; 10 of 20 in light work). The balance tended to be less negative at the highest intakes, but there were many exceptions to this generalization. For example, the following comparisons are informative:

Regimen	K Intake mEq/day	Balance in EXP II mEq/day
Light Work		
0/100/0 1000 U	0	-18
0/100/0 1000 L	0	-24
30/0/70 1000 U	28	-35
30/0/70 1000 L	29	-38
0/100/0 2000 L	0	-11
30/0/70 2000 L	52	-28
N 3000 L	61	-16
Hard Work		
ST 0 L	0	-20
15/52/33 1000 L	22	-22
30/0/70 1000 L	28	-21
0/100/0 2000 L	0	-18
15/52/33 2000 L	42	-16
N 3000 L	59	-22

So far as other factors are concerned, the following conclusions are to be drawn:

a) Caloric intake had no significant effect.

b) Work load had no consistent effect on potassium balance.

c) The protein/carbohydrate/fat ratio had little if any consistent effect. To be sure, 2/20/78 1000 U Hard Work produced the lowest balance of all, but this one result does not justify any general conclusions.

d) Water limitation had no consistent effect upon the negativity in EXP II. In hard work, dehydration actually improved negativity in six of the ten paired regimens, and in light work in five. If confirmed, this fact could have important theoretical implications: chronic dehydration alone does not influence the turnover of potassium in low calorie diets.

e) We are left with the conclusion that these experimental conditions led uniformly to negative potassium balance in all groups of subjects, a situation very much like that of chloride balance and water balance. The explanation of this non-specific effect is not clear, but the most attractive hypothesis is that there was a true catabolic phase in our subjects.

Recovery Period. Along with all other nutrients, there was a large increase of potassium intake in the recovery period. In REC I, urinary excretions approached those of the pre-period, and in REC II, far exceeded them (Table III. 147). Fecal excretion was high in REC I, and subsided to pre-period amounts in REC II (Table III. 148).

Comparison of Results in 1954 and in 1953. Technical difficulties having been overcome in the analysis of sodium and potassium, we can now speak with assurance on the results of the temperate study of 1953. There was fairly close similarity between the 1954 light work subjects and the subjects in the temperate study of 1953: All regimens produced negative balances, regardless of all other conditions. This phenomenon deserves close study. Perhaps the potassium intake in survival rations should be considered an important variable.

TABLE III. 145

PRE-PERIOD DATA ON URINARY AND FECAL POTASSIUM AND INTAKE
(mEq/day)

	P I		P II	
Flight	Mean	Range	Mean	Range
		Urine		
1	66	22-104	57	33-88
2	66	45-83	60	34-102
3	63	37-85	58	44-75
4	60	43-80	53	36-75
		Feces		
1	12	4-17	10	3-17
2	14	3-23	10	2-17
3	12	3-22	10	3-16
4	11	5-24	8	3-13
		Intake		
1	66	25-101	60	35-100
2	73	38-120	71	31-118
3	60	34-113	65	50-85
4	59	43-85	61	46-77

TABLE III. 146

POTASSIUM INTAKE
(mEq/day)

Experimental Regimen		Hard Work					Light Work				
		Pre		Exp		Rec	Pre		Exp		Rec
		I	II	I	II	I	I	II	I	II	I
ST 0	U	70	61	0	0	97	54	56	0	0	87
	L	84	81	0	0	95	59	58	0	0	90
0/100/0	U	60	48	0	0	114	60	60	0	0	74
1000	L	90	89	0	0	110	47	48	0	0	66
0/100/0	U	66	60	0	0	114	91	84	0	0	99
2000	L	87	69	0	0	86	63	68	0	0	83
2/20/78	U	94	82	3	3	113	36	60	3	3	99
1000	L	50	42	3	3	75	62	64	3	3	88
2/20/78	U	90	79	6	6	112	49	72	6	6	116
2000	L	66	62	6	6	92	64	70	6	6	100
15/52/33	U	65	56	22	22	112	56	56	22	22	86
1000	L	65	64	22	22	107	52	54	22	22	89
15/52/33	U	50	50	42	42	97	58	63	42	42	76
2000	L	59	70	42	42	94	55	56	42	42	64
15/52/33	U	71	57	61	61	59	60	56	62	61	117
3000	L	72	81	61	59	78	67	72	61	61	82
30/0/70	U	39	65	28	28	114	89	74	26	28	118
1000	L	88	82	28	28	105	58	57	28	29	85
30/0/70	U	50	50	54	55	89	52	58	54	54	118
2000	L	61	64	42	54	103	68	62	55	52	100

TABLE III. 147

URINARY POTASSIUM
(mEq/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	67	54	39	30	48	97	62	57	31	30	55	93
	L	61	65	38	18	42	84	60	51	35	33	60	99
0/100/0	U	74	62	45	30	62	112	56	50	24	15	39	122
1000	L	67	74	31	18	51	83	48	40	28	21	26	70
0/100/0	U	92	51	43	29	40	110	74	70	30	15	62	111
2000	L	64	53	20	13	44	78	74	72	26	9	50	92
2/20/78	U	62	60	38	31	68	110	42	47	26	21	53	96
1000	L	62	44	36	32	46	88	54	45	34	28	58	89
2/20/78	U	74	75	52	33	82	69	68	64	29	31	52	109
2000	L	70	52	31	26	55	86	69	64	30	32	66	96
15/52/33	U	61	58	66	56	64	118	52	48	36	42	48	116
1000	L	76	60	40	42	55	101	63	51	43	40	57	92
15/52/33	U	46	45	66	56	54	76	61	54	46	47	62	82
2000	L	60	60	53	55	54	100	58	57	59	59	48	80
15/52/33	U	68	61	69	68	62	76	79	71	79	83	86	122
3000	L	66	65	72	68	54	80	60	60	62	57	48	72
30/0/70	U	54	47	44	29	52	98	80	71	45	56	68	132
1000	L	67	65	51	46	56	96	58	46	46	63	44	76
30/0/70	U	63	55	68	56	58	96	56	48	62	54	64	100
2000	L	66	56	54	58	54	118	58	51	64	74	51	84

TABLE III. 148

FECAL POTASSIUM
(mEq/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	13	12	4	3	28	12	9	7	4	6	12	13
	L	12	13	2	2	22	8	9	10	1	1	22	13
0/100/0	U	11	9	4	8	21	19	12	10	2	4	12	7
1000	L	18	14	2	2	29	12	10	12	2	2	12	8
0/100/0	U	15	10	2	4	24	14	14	14	3	3	15	12
2000	L	14	10	6	6	22	15	12	6	2	2	13	10
2/20/78	U	16	11	6	4	24	10	10	11	6	6	20	12
1000	L	13	3	2	3	16	13	18	6	4	4	12	6
2/20/78	U	14	12	10	5	20	10	12	11	6	5	22	12
2000	L	16	12	4	4	31	14	10	6	2	2	6	4
15/52/33	U	12	10	4	5	27	15	15	8	12	8	21	16
1000	L	8	4	1	2	11	6	12	9	4	4	8	8
15/52/33	U	10	8	4	4	30	14	14	12	14	8	10	11
2000	L	18	9	4	3	21	16	6	8	4	4	10	6
15/52/33	U	15	12	13	10	14	12	8	12	10	9	31	10
3000	L	14	12	8	14	16	16	10	7	10	10	12	6
30/0/70	U	8	10	12	10	20	17	18	9	4	8	18	20
1000	L	16	10	3	3	26	12	18	10	4	4	16	18
30/0/70	U	5	8	6	3	13	10	12	10	10	8	18	9
2000	L	8	7	5	3	18	12	11	6	6	6	6	16

TABLE III. 149

POTASSIUM BALANCE
(mEq/day)

Experimental Regimen		Hard Work					Light Work				
		Pre		Exp		Rec	Pre		Exp		Rec
		I	II	I	II	I	I	II	I	II	I
ST 0	U	-10	- 5	-43	-32	+20	-17	- 9	-35	-35	+20
	L	+10	+ 4	-40	-20	+29	-10	- 3	-36	-34	+ 9
0/100/0	U	-26	-23	-48	-38	+32	- 9	- 6	-26	-18	+24
1000	L	+ 5	0	-33	-20	+30	-10	- 4	-30	-24	+28
0/100/0	U	-40	+ 6	-45	-33	+52	+ 4	0	-33	-18	+22
2000	L	+ 8	+ 2	-26	-18	+20	-23	-10	-28	-11	+20
2/20/78	U	+14	+11	-41	-32	+20	-15	+ 2	-30	-25	+25
1000	L	-25	- 5	-36	-32	+14	-10	+12	-36	-30	+19
2/20/78	U	+ 2	-22	-56	-37	+10	-31	- 2	-29	-30	+41
2000	L	-22	- 4	-28	-24	+ 6	-15	0	-26	-28	+30
15/52/33	U	- 8	-12	-48	-38	+20	-12	0	-27	-28	+17
1000	L	-20	0	-19	-22	+41	-22	- 6	-24	-22	+24
15/52/33	U	- 6	- 4	-28	-18	+17	-14	- 3	-18	-12	+ 4
2000	L	-20	- 2	-16	-16	+18	- 9	-10	-21	-21	+ 6
15/52/33	U	- 8	-16	-21	-17	-18	-26	-18	-27	-31	0
3000	L	- 7	- 2	-20	-22	+ 8	- 2	+ 4	-10	-16	+22
30/0/70	U	-22	+ 8	-28	-10	+39	-10	- 6	-22	-35	+32
1000	L	+ 4	+ 6	-26	-21	+23	-18	+ 2	-22	-38	+25
30/0/70	U	-18	-12	-20	- 4	+18	-15	+ 2	-18	- 8	+34
2000	L	-14	+ 1	-16	- 8	+31	- 1	+ 4	-14	-28	+44

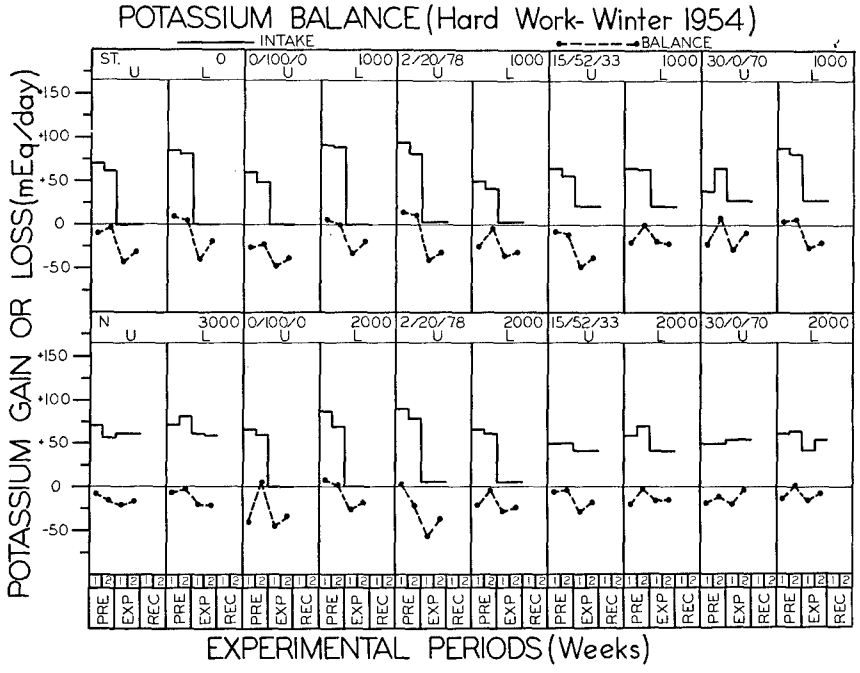

FIGURE III. 49

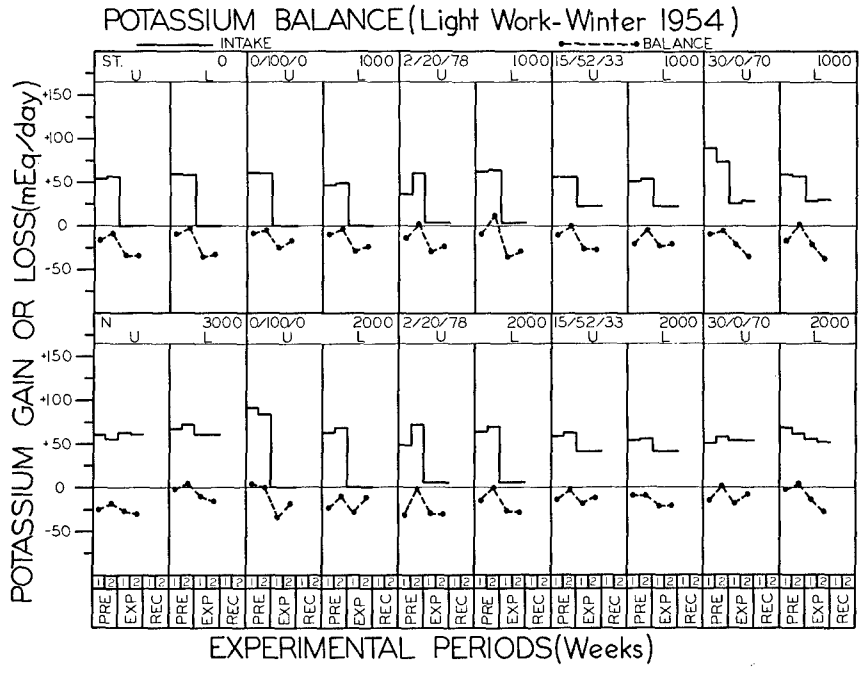

FIGURE III. 50

7. Calcium Intake And Urinary Output

Calcium deficiency is unlikely to be potentially deleterious in periods as short as two weeks. In the 1953 temperate study, calcium balance proved non-discriminatory on the relative merits of the different regimens. In the 1954 cold weather test, little emphasis was placed on calcium.

Pre-Period. Urinary excretion of calcium was much the same for any given flight in P I and P II (Table III. 150). The values were a little lower than in the 1953 temperate pre-periods, presumably because the calcium intake in 1954 was less than in 1953, owing to the omission of certain dairy products high in calcium (Table III. 151). There was a wide variation in individual men and flights, and this is the usual finding for young men.

Experimental Period. Dietary considerations, in arriving at the actual regimens used, were responsible for the fact that the calcium intake of all regimens was very low (Table III. 151). There was a decreased urinary excretion between P II and EXP I among 19 of the 20 regimens in hard work, and among all 20 in light work (Table III. 152). In EXP II there was a further decrease in 17 of the 20 hard work regimens, and in 14 of the light work regimens. Examination of the data should be made with the fact in mind that urinary excretion of calcium tends to be a highly individual characteristic. Some subjects seem always to excrete small amounts; others, characteristically large amounts. For examples, see 2/20/78 2000 U and L, Hard Work, and 30/0/70 1000 U and L, Light Work. Hence, no really convincing correlations can be discerned between urinary calcium excretion in the urine and caloric intake, work load, water intake, or percentage of protein, carbohydrate and fat in all but one of the regimens. The one suggestive finding confirms the temperate study of 1953, in that pure carbohydrate tended to depress the urinary excretion of calcium. In all 40 regimens values of less than 60 mg/day were obtained in six regimens, and four of these regimens were 0/100/0, and two were 15/52/33. This observation should be studied further because of its theoretical implications.

Recovery Period. Calcium intake in REC I exceeded that in P I for all but two pairs of subjects: 15/52/33 3000 L, Hard Work, and 0/100/0 2000 L, Light Work (Table III. 151). In REC II there was a further substantial increase in all subjects, mostly because of a large increase in consumption of dairy products. In contrast to the intake, urinary excretion of calcium in REC I exceeded that of P I in only 27 of the 40 subject sub-groups, and REC II values exceeded REC I values in only 25 of the 40 sub-groups. This was so in the face of a very substantial increase in calcium intake in REC II.

TABLE III. 150

PRE-PERIOD DATA ON URINARY CALCIUM
(mg/day)

	P I		P II	
Flight	Mean	Range	Mean	Range
1	208	129-348	211	94-331
2	163	55-283	171	63-290
3	217	85-358	232	85-380
4	172	93-315	179	85-286

TABLE III. 151

CALCIUM INTAKE
(gm/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	0.73	0.62	0.02	0.02	1.22	2.50	0.42	0.42	0.02	0.03	1.00	2.46
	L	1.03	1.13	0.01	0.02	1.21	2.47	0.56	0.67	0.01	0.01	1.08	2.22
0/100/0	U	0.83	0.63	0.03	0.03	1.60	2.55	0.46	0.42	0.02	0.02	0.85	2.27
1000	L	1.29	1.32	0.01	0.01	1.47	2.23	0.40	0.49	0.02	0.02	0.66	2.31
0/100/0	U	0.82	0.71	0.01	0.02	1.47	2.66	1.31	1.18	0.02	0.02	1.38	2.46
2000	L	1.11	0.88	0.02	0.02	1.03	2.00	0.82	1.09	0.01	0.02	1.06	2.32
2/20/78	U	1.15	0.98	0.07	0.06	1.37	2.47	0.66	0.88	0.06	0.07	1.29	2.45
1000	L	0.70	0.60	0.05	0.05	0.98	2.47	0.68	0.78	0.05	0.05	1.07	2.30
2/20/78	U	1.18	0.97	0.11	0.11	1.57	2.37	0.65	1.11	0.10	0.12	1.45	2.37
2000	L	0.68	0.69	0.09	0.09	1.20	2.38	0.79	0.84	0.09	0.09	1.34	2.38
15/52/33	U	0.74	0.67	0.23	0.14	1.45	2.65	0.62	0.59	0.13	0.13	1.01	2.66
1000	L	1.00	1.02	0.12	0.12	1.46	2.39	0.71	0.72	0.12	0.12	1.24	2.14
15/52/33	U	0.61	0.63	0.18	0.18	1.33	2.34	0.54	0.76	0.18	0.18	1.02	2.20
2000	L	0.49	0.68	0.17	0.17	1.32	2.54	0.69	0.74	0.17	0.17	0.94	2.20
15/52/33	U	0.90	0.82	0.26	0.26	0.91	2.01	0.74	0.88	0.25	0.26	1.66	2.56
3000	L	1.03	1.19	0.24	0.23	1.00	2.18	0.81	0.95	0.24	0.24	1.10	2.13
30/0/70	U	0.55	0.96	0.06	0.07	1.49	2.81	1.20	0.90	0.06	0.06	1.53	2.67
1000	L	1.18	1.28	0.05	0.05	1.38	2.37	0.78	0.74	0.05	0.05	1.22	2.35
30/0/70	U	0.62	0.65	0.09	0.10	1.15	2.20	0.56	0.63	0.10	0.10	1.21	2.28
2000	L	0.47	0.48	0.06	0.08	1.47	2.20	0.80	0.68	0.08	0.07	1.41	2.25

TABLE III. 152

URINARY CALCIUM
(mg/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	151	164	84	63	229	259	191	235	119	94	245	302
	L	130	152	85	68	154	192	201	190	132	127	244	220
0/100/0	U	270	278	131	104	332	350	236	274	71	46	270	398
1000	L	212	272	89	44	200	278	222	248	104	84	236	252
0/100/0	U	291	220	116	89	261	296	211	202	74	49	194	219
2000	L	194	186	75	61	182	202	220	240	86	57	260	229
2/20/78	U	154	166	86	88	150	196	152	144	126	126	236	216
1000	L	166	205	134	126	276	344	200	202	119	124	232	257
2/20/78	U	304	277	92	123	240	219	206	166	152	210	256	246
2000	L	155	146	100	74	216	180	168	171	100	128	176	195
15/52/33	U	282	224	126	116	352	380	283	270	124	86	304	382
1000	L	149	122	60	57	123	122	164	158	88	69	152	158
15/52/33	U	220	254	138	130	236	289	274	348	168	132	281	336
2000	L	208	214	90	79	240	322	101	143	71	65	124	121
15/52/33	U	166	244	96	80	162	160	210	213	136	123	227	218
3000	L	127	125	60	57	160	126	168	181	92	84	181	188
30/0/70	U	164	190	133	130	311	306	237	256	148	128	276	340
1000	L	176	164	136	128	252	302	166	166	83	93	208	176
30/0/70	U	134	134	143	156	161	166	194	216	149	166	312	378
2000	L	148	138	112	110	288	288	110	96	74	65	194	140

8. Phosphorus Intake And Urinary Output

Phosphorus may be a nutrient of considerable importance in survival rations, as the work of 1953 suggested. Unfortunately, in the 1954 winter test it was not possible to pay as much attention to it as one would like. Fecal analyses are not available, and therefore only a descriptive narrative of urinary phosphate excretion can be given at this time.

Pre-Period. Urinary excretion ranged from 0.88 gm P/day to 0.98 gm P/day in the two pre-period weeks (Table III. 153). The mean values for all four flights were constant between P I and P II. These values were much the same as for the 1953 subjects, and showed about the same variation from individual to individual. By National Research Council standards, dietary phosphorus was adequate or even high in the pre-period (Table III. 154). The average was over 1 gm/day, and the extreme range, 0.81 to 1.93 gm/day.

Experimental Period. A wide range of phosphorus intakes was encountered in the experimental weeks; the lowest was zero in starvation and 0/100/0 and the highest 1.19 gm/day in 30/0/70 2000. Urinary excretion of phosphorus tended to correlate with intake, being greatest in those regimens of greatest phosphorus intake (Table III. 155). There was a tendency for urinary excretion to be lower in P II than in P I, but not in all regimens. This tendency was consistent in low phosphorus regimens, but not in high.

So far as other factors were concerned, caloric intake had little if any effect. However, work load did seem to have some influence. In 20 paired comparisons, the urinary excretion in EXP II of the hard work pair was greater in 13.

Limitation of water also had an effect in a majority of cases. In 20 comparisons of U vs L in EXP II, L was greater in 15. This is one of the few specific effects of dehydration on nutrient balance to be detected in this present study.

The ratio of protein/carbohydrate/fat also affected the urinary phosphorus excretion. At a given phosphorus intake, increase of carbohydrate decreased the phosphorus excretion; increase of protein under the same conditions increased the phosphorus excretion.

Recovery Period. During REC I, phosphorus intake exceeded that of P II in all sub-groups in all four flights (Table III. 154), and there was a further substantial increase in REC II, because of dairy products and fresh meat that were offered in the diet of that week. In spite of these differences in intake, the urinary excretion in REC I was lower than that in P II in 37 of the 40 comparisons. In REC II, in spite of an intake about twice that of P II, the urinary phosphorus excretion was only slightly greater.

These findings in recovery are very suggestive. When fecal data become available, an interpretation in terms of balance will be possible. Meanwhile, it is possible to postulate that a true anabolic phase was in process during REC I in all subjects, even those previously on a high protein-high phosphorus diet in EXP I and EXP II. During this anabolic phase, protein and high energy phosphate bonds were being sythesized at a spectacular rate.

It is possible to make one generalization on balance in EXP II. Urinary excretion was greater than intake in 37 of 40 regimens. Therefore, practically all sub-groups were in negative balance, sometimes of substantial degree, especially in the low phosphorus regimens. We interpret this as evidence of a non-specific factor common to all subjects, and it fits the picture of a catabolic phase.

TABLE III. 153

PRE-PERIOD DATA ON URINARY PHOSPHORUS
(gm P/day)

	P I		P II	
Flight	Mean	Range	Mean	Range
1	0.97	0.61-1.32	0.90	0.62-1.28
2	0.91	0.65-1.21	0.96	0.67-1.40
3	0.98	0.73-1.21	0.92	0.66-1.18
4	0.88	0.72-1.05	0.90	0.69-1.10

TABLE III. 154

PHOSPHORUS INTAKE
(gm P/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST O	U	1.32	1.21	0.00	0.00	2.06	3.57	1.22	1.18	0.00	0.00	1.93	3.42
	L	1.64	1.63	0.00	0.00	2.04	3.45	1.29	1.19	0.00	0.00	2.04	3.00
0/100/0	U	1.36	0.96	0.00	0.00	2.36	3.62	1.27	1.21	0.00	0.00	1.76	3.19
1000	L	1.79	1.76	0.00	0.00	2.29	2.95	1.31	1.03	0.00	0.00	1.65	2.99
0/100/0	U	1.36	1.19	0.00	0.00	2.43	3.66	1.69	1.51	0.00	0.00	2.09	3.15
2000	L	1.69	1.34	0.00	0.00	1.78	2.71	1.37	1.41	0.00	0.00	1.89	3.04
2/20/78	U	1.93	1.57	0.16	0.16	2.37	3.62	0.81	1.29	0.15	0.16	2.11	3.42
1000	L	1.09	1.01	0.16	0.16	1.70	3.62	1.38	1.33	0.16	0.16	1.93	3.14
2/20/78	U	1.84	1.59	0.41	0.41	2.35	3.02	1.14	1.67	0.36	0.41	2.46	3.59
2000	L	1.40	1.37	0.41	0.41	2.02	3.48	1.42	1.45	0.41	0.41	2.14	3.27
15/52/33	U	1.39	1.09	0.41	0.41	2.40	3.60	1.37	1.30	0.41	0.41	2.04	3.78
1000	L	1.42	1.40	0.41	0.41	2.17	3.32	1.26	1.22	0.41	0.41	1.96	2.81
15/52/33	U	1.02	1.10	0.71	0.71	2.09	3.26	1.18	1.38	0.71	0.71	1.78	2.66
2000	L	1.21	1.46	0.71	0.71	1.93	3.39	1.23	1.14	0.71	0.71	1.46	2.83
15/52/33	U	1.52	1.24	1.07	1.07	1.43	2.78	1.34	1.39	1.08	1.07	2.47	3.56
3000	L	1.61	1.67	1.07	1.04	1.68	2.81	1.47	1.44	1.07	1.07	1.82	2.79
30/0/70	U	0.88	1.26	0.58	0.59	2.36	3.80	1.79	1.47	0.57	0.61	2.44	3.52
1000	L	1.69	1.58	0.59	0.59	2.20	3.32	1.26	1.20	0.59	0.62	1.90	3.16
30/0/70	U	1.15	1.02	1.09	1.19	1.83	3.09	1.12	1.04	1.15	1.16	2.02	2.99
2000	L	1.24	1.27	0.92	1.12	2.25	3.83	1.40	1.25	1.19	1.12	2.11	2.94

TABLE III. 155

URINARY PHOSPHORUS
(gm/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	0.98	0.90	0.96	0.63	0.66	1.24	0.88	0.85	0.88	0.72	0.78	0.95
	L	0.89	0.97	1.03	0.89	0.34	1.09	0.85	0.94	1.00	0.73	0.53	1.09
0/100/0	U	1.02	1.01	0.64	0.63	0.79	1.38	0.96	0.88	0.55	0.37	0.35	1.34
1000	L	0.89	1.01	0.69	0.58	0.48	1.13	0.76	0.76	0.64	0.55	0.49	0.96
0/100/0	U	1.18	0.89	0.68	0.47	0.76	1.60	1.03	0.92	0.58	0.32	0.78	1.20
2000	L	0.87	0.92	0.46	0.47	0.49	1.15	0.86	0.94	0.57	0.36	0.58	1.08
2/20/78	U	0.96	0.96	0.84	0.79	0.70	1.34	0.86	0.84	0.72	0.55	0.34	1.10
1000	L	0.86	0.87	0.94	0.85	0.81	1.01	0.86	0.84	0.78	0.63	0.52	1.04
2/20/78	U	1.03	1.14	0.84	0.61	1.00	1.41	0.97	0.98	0.75	0.60	0.63	1.08
2000	L	0.82	0.94	0.69	0.63	0.49	1.14	0.99	1.02	0.72	0.70	0.82	1.12
15/52/33	U	1.04	0.88	0.85	0.86	0.98	1.57	0.98	0.87	0.78	0.67	0.54	1.41
1000	L	0.93	0.98	0.75	0.86	0.36	1.08	0.90	0.81	0.72	0.65	0.52	1.09
15/52/33	U	0.82	0.74	0.90	0.85	0.78	1.36	1.06	1.04	0.82	0.81	0.80	1.05
2000	L	0.89	1.04	0.95	0.87	0.34	0.68	0.90	0.81	0.94	1.02	0.56	0.86
15/52/33	U	1.00	0.94	1.04	0.92	0.86	1.30	1.13	1.08	1.20	1.06	1.02	1.34
3000	L	0.95	0.94	1.15	1.20	0.57	0.88	0.97	1.10	1.13	0.78	0.66	0.94
30/0/70	U	0.80	0.76	0.94	0.95	0.56	1.50	1.15	1.04	1.27	1.12	0.57	1.20
1000	L	1.00	0.96	1.31	1.19	0.43	0.94	0.90	0.89	1.11	1.26	0.67	1.00
30/0/70	U	0.82	0.77	1.44	1.34	0.61	1.20	0.82	0.70	1.42	1.42	0.65	1.09
2000	L	1.04	0.98	1.37	1.70	0.60	1.50	0.87	0.84	1.51	1.44	0.88	1.06

9. Acid-Base Balance

Urinary Acidity. Two measures of urinary acidity were used: (a) titrable acidity and (b) pH (by glass electrode). Both these determinations were carried out on the urine collected during the weekly two-hour test. The pre-period means and ranges for these measures of acidity for the five groups of subjects are summarized in Table III. 156. The subjects of four flights tended to excrete a less acid urine than the control subjects. The former were subsisting on the 5-in-1 ration, the latter on a standard garrison ration.

Urinary pH. The data in Table III. 157 reveal that there were large changes in the acidity of the urine during the course of the investigation.

Control subjects: The men in hard work flights showed no variation in urinary pH. The controls in the light work flights excreted more alkaline urine during the second week of the experimental period.

Work load: Except for the differences in the two control groups, work load had no appreciable effect on urinary pH.

Water intake: The weekly variations in urinary pH were not significantly influenced by the water intake.

Nutrient combinations: Three nutrient combinations evoked rather large changes in urinary pH. The 0/100/0 and 2/20/78 regimens were associated with production of strongly alkaline urine when fed at 2000 Cal/day. At 1000 Cal/day the alkaline trend was only evident for the light work group subsisting on 0/100/0. pH values exceeding 8.0 are quite remarkable. Such an alkalosis was not observed in the studies of the winter of 1953 among subjects living under normal conditions. The 30/0/70 regimen regularly produced a relatively more acid urine. This finding confirms the work of the winter of 1953.

Recovery: The first and second weeks of recovery were strikingly different. In the first week three types of reactions were evident: (a) no change, (b) maintenance of relatively alkaline urine, and (c) marked alkaline rebound. The latter reaction was especially marked in the case of men who had subsisted on 30/0/70. In the second week of recovery --- the subjects switched from 5-in-1 ration to garrison ration --- there was a rather uniform trend toward production of a much more acid urine. In the majority of the subjects pH values were lower than the mean values for the flight leaders during the pre-periods. The reason for this trend undoubtedly lies in the higher acid ash content of the garrison ration as compared to the 5-in-1 ration.

Titrable Acidity. The weekly observations on titrable acidity are presented in tabular form (Table III. 158). The trends are similar to those for urinary pH and clearly illustrate the wide variations in acidity evoked by the changes in caloric intake and nutrient mixtures. The large excretion of titrable acidity associated with subsistence on 30/0/70 was most probably due to the greatly increased excretion of ketone bodies in the urine during that regimen (Figures III. 51 and 52).

Urinary Ammonia. When the kidney is called upon to excrete increased amounts of acid metabolites, the tubular epithelium produces more ammonia. This ammonia replaces sodium and is excreted with the acid radicals. The two-hour urines were analyzed for ammonia to study (a) whether the kidney reacted normally by producing more ammonia when the titrable acidity increased and (b) whether the expected increase failed to occur, suggesting renal tubular functional impairment.

The pre-period data for the five groups of subjects are summarized in Table III. 159. These values compare very well with normal figures reported in the literature (Sargent et al., 1954).

Experimental regimens: The controls maintained a relatively constant rate of excretion of urinary ammonia (Table III. 160 and Figures III. 53 and 54). Only in a general way did the excretion of ammonia parallel that of titrable acidity in the case of the experimental subjects.

Three patterns of variation were discernible in the urinary ammonia: (a) decrease to lower than control values in both EXP I and EXP II (ST 0 and 0/100/0), (b) decrease in EXP I with rise to control level or above in EXP II (2/20/78 and 15/52/33) and (c) increase above control values in both EXP I and EXP II (30/0/70). These patterns were accentuated in the light work groups and ST 0 and 0/100/0 move to type b. In general, limitation of water markedly reduces the variability and in many cases the patterns almost disappear. Actually most of these variations are within the pre-period normal range (mean $\pm$ 2 x s.d.). On the other hand, the persistence of trends and their accentuation by a sedentary existence suggests that they were provoked by the experimental regimens. There are no grounds for suspecting renal tubular damage from these results, the changes in urinary ammonia being conditioned by metabolic changes rather than renal functional alterations.

Recovery: Confirming the trends toward relative acidosis in the second week of recovery, there was a marked increase in the output of urinary ammonia at this time. This increase was significant, for the values generally exceeded the pre-period mean by more than three standard deviations.

Ketonuria. Qualitative reactions for ketone bodies were performed on urine collected during the two-hour test and on daily urinary specimens from all subjects (except controls) collected from Day 13 to Day 30 of the study. The latter period included the two-week experimental period extending from Day 15 to Day 28. The procedure of Rothera was used.

Two-hour urine test: Data for the controls are shown in Table III. 161. It is noteworthy that a number of positive reactions were observed. In all, 25.4% of the 68 specimens were positive. Two of the strongest reactions occurred among flight leaders ill with upper respiratory infections. Most of the positive reactions occurred between weeks 1 and 4. Only one positive reaction was noted in weeks 5 and 6.

The pre-period and recovery data for the 87 volunteer airmen are comparable (Table III. 162). Of 158 two-hour specimens tested in weeks 1 and 2, 25.8% were

positive. In weeks 5 and 6 only one of 174 two-hour specimens was positive. It is doubtful that the high incidence of positive reactions can be attributed to acute respiratory infections.

Daily urine specimens: Many of the nutrient regimens were associated with consistent occurrence of ketonuria during the period at Camp McCoy (Table III. 163). Strongly positive reactions were present in the daily urine from men subsisting on ST 0, 30/0/70 1000 and 2000, and 2/20/78 1000 and 2000. In the 1953 winter tests only starvation and the meat bar diet caused comparable ketonuria. These findings suggest that exposure to cold weather may have been a factor in causing the more general occurrence of ketonuria in 1954.

In all, 1141 daily specimens were tested for acetone bodies. All regimens except 0/100/0 2000 and 15/52/33 3000 L, Hard Work, were associated with some degree of ketonuria (Table III. 164). Further scrutiny of the data brings out two major points (Table III. 165).

a) 250 gm of carbohydrate, which was the amount in 0/100/0 1000, was not enough completely to prevent moderate ketonuria even in men performing light work. This finding does not agree with Gamble's (1947) report that 200 gm of carbohydrate is sufficient to inhibit ketonuria. Since his research was done on sedentary subjects in the summer, it may be that his conclusions do not apply when the castaway is exposed to cold (Sargent, 1954).

b) If we adopt the criterion that a decreased severity of ketonuria in EXP II is evidence of adaptation to metabolic acidosis, our data would suggest no adaptation to meat bar occurred, whereas in the balanced regimen 15/52/33, adaptation did occur. The failure to find adaptation among more of these regimens is consistent with the general catabolic reaction which has been described earlier in this section.

TABLE III. 156

PRE-PERIOD DATA ON URINARY pH AND TITRABLE ACIDITY

Groups of Subjects	P I Mean	P I Range	P II Mean	P II Range
		Urinary pH		
Flight 1	6.49	5.49-7.18	5.87	5.18-7.00
Flight 2	6.70	5.61-7.81	6.29	5.35-7.58
Flight 3	6.66	5.40-8.00	6.61	5.65-7.30
Flight 4	6.46	5.58-7.35	6.20	5.40-7.15
Controls	5.88	5.25-7.25	5.90	5.00-7.15
		Titrable Acidity, microequivalents/min		
Flight 1	7.2	0.0-26.7	10.7	0.0-19.4
Flight 2	5.1	0.0-19.7	12.9	0.0-34.5
Flight 3	6.5	0.0-22.5	7.6	0.0-20.8
Flight 4	6.6	0.0-14.9	8.0	0.0-20.3
Controls	15.5	0.0-40.2	10.5	0.0-22.4

TABLE III. 157

ACID-BASE BALANCE: URINARY pH

Experimental Regimen		Hard Work					Light Work				
		Pre*	Exp		Rec		Pre*	Exp		Rec	
			I	II	I	II		I	II	I	II
ST 0	U	6.15	6.31	7.08	6.40	5.53	6.40	6.04	6.44	6.37	6.95
	L	6.72	6.36	5.91	5.94	5.87	6.05	5.85	6.10	6.06	5.75
0/100/0	U	6.62	6.94	6.40	6.82	5.66	6.55	7.30	7.34	6.88	6.05
1000	L	6.30	6.30	6.74	6.16	6.65	6.01	7.12	6.59	6.85	5.76
0/100/0	U	6.22	8.10	7.92	7.18	5.60	7.21	7.96	7.90	7.15	5.86
2000	L	6.83	7.31	7.44	5.58	5.32	6.66	7.44	7.45	6.35	5.54
2/20/78	U	6.52	6.62	6.10	7.45	6.65	7.05	6.45	6.60	7.10	5.78
1000	L	6.66	6.04	6.12	5.80	5.87	6.81	5.92	6.35	7.00	6.39
2/20/78	U	6.34	6.16	7.55	6.32	5.48	6.72	6.74	7.59	7.02	5.54
2000	L	6.57	7.21	7.15	6.08	5.65	6.60	6.32	7.62	7.04	5.89
15/52/33	U	5.91	6.50	6.75	7.14	5.96	6.79	7.50	7.26	6.94	6.48
1000	L	6.27	5.82	6.15	6.30	6.42	5.92	6.78	7.60	7.08	6.12
15/52/33	U	6.24	6.46	7.15	7.01	5.40	6.88	7.05	6.69	7.39	6.22
2000	L	7.08	5.97	5.58	7.10	6.33	6.21	5.85	5.95	6.65	5.90
15/52/33	U	5.84	6.47	5.44	6.48	5.48	6.19	6.20	6.42	6.95	6.90
3000	L	6.15	6.48	6.60	5.32	5.17	7.20	5.95	7.39	6.90	6.19
30/0/70	U	5.77	6.10	5.80	7.35	5.39	6.45	6.25	5.82	7.01	5.96
1000	L	6.62	6.00	5.42	7.32	5.35	5.69	5.52	5.72	6.73	5.49
30/0/70	U	5.72	6.12	5.18	6.65	5.45	6.48	6.30	5.62	6.22	5.30
2000	L	5.89	6.12	5.45	6.52	5.71	6.36	5.33	5.62	6.90	5.58
Control	U	6.25	6.40	6.06	6.98	6.33	5.44	6.02	7.76	6.53	6.02
	L	6.50	6.54	6.19	5.69	5.45	5.42	6.56	7.19	6.71	6.69

*Mean values for PI and PII.

TABLE III. 158

ACID-BASE BALANCE: URINARY TITRABLE ACIDITY
(microEq/min)

Experimental Regimen		Hard Work Pre*	Exp I	Exp II	Rec I	Rec II	Light Work Pre*	Exp I	Exp II	Rec I	Rec II
ST 0	U	10.6	14.5	0.6	3.2	30.6	10.3	19.9	8.8	6.7	0.8
	L	8.7	18.2	20.5	6.4	23.0	9.4	13.0	8.4	14.4	26.1
0/100/0	U	5.4	4.6	3.0	0.5	31.9	6.4	0.6	0.0	5.0	18.4
1000	L	13.7	18.3	2.4	6.6	2.1	9.8	1.9	3.5	1.7	18.1
0/100/0	U	12.2	0.0	0.0	0.0	28.1	8.1	0.0	0.0	4.2	11.8
2000	L	3.6	3.2	0.0	13.1	19.5	6.1	0.0	0.0	9.0	21.8
2/20/78	U	6.8	12.5	5.8	0.0	17.6	2.4	11.5	5.4	0.3	22.8
1000	L	10.7	16.4	7.7	4.1	19.7	2.7	12.6	6.6	0.6	8.1
2/20/78	U	7.6	25.8	2.6	8.5	42.2	2.3	12.1	0.0	1.3	22.5
2000	L	6.9	6.2	3.7	6.7	16.6	6.2	7.6	0.0	1.2	13.5
15/52/33	U	7.7	14.8	1.8	0.0	17.6	4.2	3.9	1.1	8.8	11.8
1000	L	8.6	18.6	6.0	5.0	6.0	9.8	4.5	0.0	0.0	9.3
15/52/33	U	6.9	18.7	7.4	0.0	35.2	9.6	3.2	5.0	0.0	16.6
2000	L	0.0	21.6	18.2	0.9	8.3	8.9	14.8	15.4	2.7	12.1
15/52/33	U	8.6	17.6	26.0	5.0	23.4	6.3	10.5	11.4	0.7	21.6
3000	L	9.0	18.3	6.8	10.8	17.1	0.9	16.6	0.8	2.4	16.2
30/0/70	U	17.4	27.8	20.8	0.0	40.6	9.2	21.8	18.6	3.7	20.1
1000	L	9.8	27.3	24.4	0.0	29.8	10.2	23.2	21.8	3.3	24.8
30/0/70	U	12.3	28.4	22.0	6.4	16.3	6.4	25.5	25.2	9.2	27.6
2000	L	15.0	25.8	27.7	7.0	28.3	6.9	33.7	27.2	0.3	20.4
Control	U	10.7	14.5	12.1	2.3	10.2	13.5	8.3	0.0	4.8	9.2
	L	5.1	9.2	12.1	17.9	12.9	19.4	13.5	3.0	3.6	1.8

*Mean values for PI and PII.

TABLE III. 159

PRE-PERIOD DATA ON URINARY AMMONIA NITROGEN
(mg/min)

Groups of Subjects	P I M	P I s.d.	P I C.V.	P II M	P II s.d.	P II C.V.
Flight 1	1.18	0.33	28.0	0.65	0.26	40.0
Flight 2	0.71	0.38	53.6	0.77	0.32	41.6
Flight 3	0.74	0.19	25.7	0.64	0.18	28.1
Flight 4	0.55	0.18	32.8	0.62	0.21	33.9
Controls	0.74	0.22	29.8	0.68	0.28	41.2

TABLE III. 160

URINARY AMMONIA NITROGEN
(mg/min)

Experimental Regimen		Hard Work Pre*	Hard Work Exp I	Hard Work Exp II	Hard Work Rec I	Hard Work Rec II	Light Work Pre*	Light Work Exp I	Light Work Exp II	Light Work Rec I	Light Work Rec II
ST 0	U	0.84	0.50	0.55	1.06	1.38	0.74	1.20	1.20	1.04	1.50
	L	0.72	0.78	1.36	0.91	2.06	0.83	0.67	0.70	1.02	1.03
0/100/0	U	0.89	0.26	0.38	0.86	2.15	0.64	0.30	0.74	1.46	1.68
1000	L	1.27	0.44	0.64	0.79	1.28	0.44	0.25	0.46	0.90	1.40
0/100/0	U	0.64	0.29	0.38	1.28	1.77	0.39	0.27	0.54	0.56	1.98
2000	L	0.65	0.20	0.36	0.76	1.14	0.61	0.24	0.42	0.90	1.28
2/20/78	U	1.04	0.63	0.64	1.27	1.70	0.73	0.50	2.02	0.82	2.84
1000	L	0.58	0.70	0.50	0.58	1.83	0.43	0.68	0.60	1.00	1.16
2/20/78	U	0.76	0.42	0.91	0.74	1.48	0.67	0.53	1.45	0.78	2.06
2000	L	0.86	0.48	0.86	0.64	1.48	0.69	0.46	0.46	1.18	1.05
15/52/33	U	0.68	0.35	0.66	1.22	1.31	0.66	0.34	0.84	0.89	3.06
1000	L	0.59	0.60	0.53	0.60	0.60	0.56	0.44	0.48	1.08	2.19
15/52/33	U	0.90	0.59	1.09	1.33	1.48	0.69	0.42	0.58	0.22	1.57
2000	L	0.61	0.76	0.55	0.52	1.12	0.54	0.58	0.47	1.12	2.10
15/52/33	U	0.75	0.55	0.91	1.20	1.58	0.70	0.57	1.48	0.64	1.78
3000	L	0.80	0.85	0.68	0.58	1.34	0.68	0.77	0.55	0.96	1.78
30/0/70	U	0.91	1.06	1.19	1.37	2.59	0.93	1.08	1.78	0.78	1.72
1000	L	0.63	0.82	1.09	0.98	1.56	0.52	0.74	0.87	0.88	0.84
30/0/70	U	1.21	1.71	1.24	0.78	2.04	0.64	1.72	2.98	0.90	1.08
2000	L	0.63	1.08	1.57	0.86	2.62	0.52	1.34	1.44	1.43	2.58
Control	U	0.83	0.61	1.25	0.62	1.11	0.79	0.87	0.88	0.53	0.80
	L	0.58	0.78	1.04	0.64	0.78	0.48	0.98	1.14	0.42	1.40

*Mean values for PI and PII.

TABLE III. 161

KETONURIA AMONG RATION CONTROLS
(Two-Hour Test Urine)

Subject Code No.	Ketonuria (Rothera) (0 to +4) Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6
90	0	tr	0	0	0	0
91	0	0	0	tr	0	0
92	0	0	0	0	0	0
93	+2	+1	0	tr	0	0
94	0	0	0	0	0	0
95	0	0	0	0	0	0
96	0	tr	0	0	0	0
97	-	+4*	-	0	0	0
98	0	+2	0	0	0	0
99	+1	tr	+3*	tr	0	0
100	-	0	+1	tr	0	-
101	+1	0	tr	0	tr	0

*Acute upper respiratory infections present on day of test.

TABLE III. 162

OCCURRENCE OF POSITIVE REACTIONS FOR KETONE BODIES, EXPERIMENTAL SUBJECTS, PRE-PERIOD AND RECOVERY
(Two-Hour Test Urine)

Period	Total Tested	Intensity of Reaction					
		0	tr	+1	+2	+3	+4
Pre-Period	158	116	18	15	4	3	2
Recovery	174	173	1	0	0	0	0

TABLE III. 163

REGIMENS ASSOCIATED WITH OCCURRENCE OF 3+ OR 4+ KETONURIA

Light Work*	Hard Work*
ST 0	ST 0
30/0/70 1000	30/0/70 1000
30/0/70 2000	30/0/70 2000
2/20/78 1000	2/20/78 1000
2/20/78 2000	2/20/78 2000

*All subjects, regardless of water intake.
Both experimental weeks included.

TABLE III. 164

PERCENTAGE DISTRIBUTION OF DEGREES OF KETONURIA VS. DIET AND WORK
(Daily Specimens)

Experimental Regimen		Phase	Hard Work No. Spec.	Hard Work Intensity of Reaction 0	tr	+1	+2	+3	+4	Light Work No. Spec.	Light Work Intensity of Reaction 0	tr	+1	+2	+3	+4
ST 0	U	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	6	100.0	0.0	0.0	0.0	0.0	0.0
		E I	21	0.0	9.3	4.7	28.6	38.1	19.1	20	0.0	5.0	10.0	10.0	25.0	50.0
		E II	10	0.0	10.0	70.0	20.0	0.0	0.0	10	0.0	0.0	0.0	0.0	40.0	60.0
ST 0	L	PRE	8	100.0	0.0	0.0	0.0	0.0	0.0	6	100.0	0.0	0.0	0.0	0.0	0.0
		E I	28	0.0	3.6	14.3	25.0	25.0	32.1	21	4.7	0.0	0.0	4.7	14.3	76.1
		E II	20	0.0	5.0	30.0	20.0	40.0	5.0	10	0.0	0.0	0.0	0.0	30.0	70.0
0/100/0	U	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	3	100.0	0.0	0.0	0.0	0.0	0.0
1000		E I	14	21.4	35.7	35.7	7.1	0.0	0.0	14	71.3	21.4	7.1	0.0	0.0	0.0
		E II	10	100.0	0.0	0.0	0.0	0.0	0.0	10	100.0	0.0	0.0	0.0	0.0	0.0
0/100/0	L	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
1000		E I	14	50.0	21.4	28.6	0.0	0.0	0.0	13	30.8	15.4	46.2	7.7	0.0	0.0
		E II	10	90.0	10.0	0.0	0.0	0.0	0.0	10	20.0	30.0	40.0	0.0	0.0	0.0
0/100/0	U	PRE	2	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
2000		E I	11	100.0	0.0	0.0	0.0	0.0	0.0	14	100.0	0.0	0.0	0.0	0.0	0.0
		E II	10	100.0	0.0	0.0	0.0	0.0	0.0	10	100.0	0.0	0.0	0.0	0.0	0.0
0/100/0	L	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
2000		E I	14	100.0	0.0	0.0	0.0	0.0	0.0	13	100.0	0.0	0.0	0.0	0.0	0.0
		E II	10	100.0	0.0	0.0	0.0	0.0	0.0	10	100.0	0.0	0.0	0.0	0.0	0.0
2/20/78	U	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	3	100.0	0.0	0.0	0.0	0.0	0.0
1000		E I	14	0.0	7.1	0.0	14.3	28.6	50.0	13	0.0	7.7	7.7	0.0	22.1	61.5
		E II	10	0.0	0.0	0.0	0.0	50.0	50.0	10	0.0	0.0	0.0	0.0	30.0	70.0
2/20/78	L	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
1000		E I	14	0.0	7.1	28.6	50.0	14.3	0.0	14	7.1	0.0	7.1	0.0	57.2	28.6
		E II	10	0.0	0.0	50.0	50.0	0.0	0.0	10	0.0	0.0	0.0	20.0	40.0	40.0
2/20/78	U	PRE	2	100.0	0.0	0.0	0.0	0.0	0.0	4	75.0	25.0	0.0	0.0	0.0	0.0
2000		E I	7	14.3	0.0	28.6	42.8	14.3	0.0	20	10.0	5.0	20.0	25.0	30.0	10.0
		E II	5	0.0	0.0	80.0	0.0	20.0	0.0	10	0.0	0.0	30.0	40.0	30.0	0.0
2/20/78	L	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
2000		E I	14	14.3	7.1	28.6	50.0	7.1	0.0	14	0.0	14.3	28.6	42.8	7.1	7.1
		E II	10	0.0	0.0	80.0	20.0	0.0	0.0	10	0.0	0.0	40.0	30.0	30.0	0.0

TABLE III. 164 (Cont.)

PERCENTAGE DISTRIBUTION OF DEGREES OF KETONURIA VS. DIET AND WORK
(Daily Specimens)

Experimental Regimen		Phase	Hard Work No. Spec.	Hard Work Intensity of Reaction 0	tr	+1	+2	+3	+4	Light Work No. Spec.	Light Work Intensity of Reaction 0	tr	+1	+2	+3	+4
15/52/33	U	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
1000		E I	14	14.3	14.3	64.3	7.1	0.0	0.0	13	7.7	15.4	76.8	0.0	0.0	0.0
		E II	10	10.0	10.0	80.0	0.0	0.0	0.0	10	20.0	80.0	0.0	0.0	0.0	0.0
15/52/33	L	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
1000		E I	14	50.0	36.7	14.3	0.0	0.0	0.0	14	64.3	35.7	0.0	0.0	0.0	0.0
		E II	10	70.0	30.0	0.0	0.0	0.0	0.0	10	60.0	40.0	0.0	0.0	0.0	0.0
15/52/33	U	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
2000		E I	13	61.5	23.1	15.4	0.0	0.0	0.0	14	14.3	35.7	42.8	7.1	0.0	0.0
		E II	10	70.0	30.0	0.0	0.0	0.0	0.0	10	70.0	20.0	10.0	0.0	0.0	0.0
15/52/33	L	PRE	3	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
2000		E I	14	50.0	42.8	7.1	0.0	0.0	0.0	14	92.7	7.1	0.0	0.0	0.0	0.0
		E II	10	90.0	10.0	0.0	0.0	0.0	0.0	10	90.0	10.0	0.0	0.0	0.0	0.0
15/52/33	U	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
3000		E I	14	78.4	14.3	7.1	0.0	0.0	0.0	14	92.7	7.1	0.0	0.0	0.0	0.0
		E II	10	80.0	0.0	10.0	0.0	10.0	0.0	10	100.0	0.0	0.0	0.0	0.0	0.0
15/52/33	L	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	75.0	25.0	0.0	0.0	0.0	0.0
3000		E I	14	100.0	0.0	0.0	0.0	0.0	0.0	14	100.0	0.0	0.0	0.0	0.0	0.0
		E II	10	100.0	0.0	0.0	0.0	0.0	0.0	10	100.0	0.0	0.0	0.0	0.0	0.0
30/0/70	U	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
1000		E I	14	0.0	0.0	0.0	21.4	7.1	71.3	14	0.0	0.0	7.1	28.6	28.6	35.7
		E II	10	0.0	0.0	0.0	0.0	20.0	80.0	10	0.0	0.0	0.0	0.0	10.0	90.0
30/0/70	L	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
1000		E I	14	0.0	0.0	0.0	14.3	21.4	64.2	14	7.1	0.0	7.1	21.4	64.3	0.0
		E II	10	0.0	0.0	0.0	10.0	40.0	50.0	10	0.0	0.0	10.0	50.0	40.0	0.0
30/0/70	U	PRE	4	75.0	25.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
2000		E I	14	0.0	7.1	0.0	7.1	28.6	57.1	14	0.0	7.1	7.1	7.1	50.0	28.6
		E II	10	0.0	0.0	0.0	0.0	40.0	60.0	10	0.0	0.0	0.0	0.0	60.0	40.0
30/0/70	L	PRE	4	100.0	0.0	0.0	0.0	0.0	0.0	4	100.0	0.0	0.0	0.0	0.0	0.0
2000		E I	14	0.0	0.0	0.0	42.7	28.6	28.6	14	0.0	0.0	28.6	50.0	21.4	0.0
		E II	10	0.0	0.0	0.0	20.0	50.0	30.0	10	0.0	10.0	30.0	30.0	20.0	10.0

TABLE III. 165

BEHAVIOR OF KETONURIA: EXP II VS. EXP I
(Daily Specimens)

No Ketonuria at Any Time: 5 Regimens

0/100/0	2000 U and L, Hard Work, Light Work
15/52/33	3000 L, Hard Work

Decreased Ketonuria in EXP II: 15 Regimens

ST	0 U and L, Hard Work
0/100/0	1000 U and L, Hard Work
0/100/0	1000 U, Light Work
2/20/78	2000 U and L, Hard Work
2/20/78	2000 L, Light Work
15/52/33	1000 L, Hard Work
15/52/33	1000 U, Light Work
15/52/33	2000 U and L, Hard Work
15/52/33	2000 U, Light Work
15/52/33	3000 U, Hard Work
30/0/70	1000 L, Light Work

Increased Ketonuria in EXP II: 5 Regimens

30/0/70	1000 U, Hard Work, Light Work
30/0/70	2000 U and L, Hard Work
30/0/70	2000 U, Light Work

No Appreciable Change in Ketonuria: 15 Regimens

ST	0 U and L, Light Work
0/100/0	1000 L, Light Work
2/20/78	1000 U and L, Hard Work, Light Work
2/20/78	2000 U, Light Work
15/52/33	1000 U, Hard Work
15/52/33	1000 L, Light Work
15/52/33	2000 L, Light Work
15/52/33	3000 U and L, Light Work
30/0/70	1000 L, Hard Work
30/0/70	2000 L, Light Work

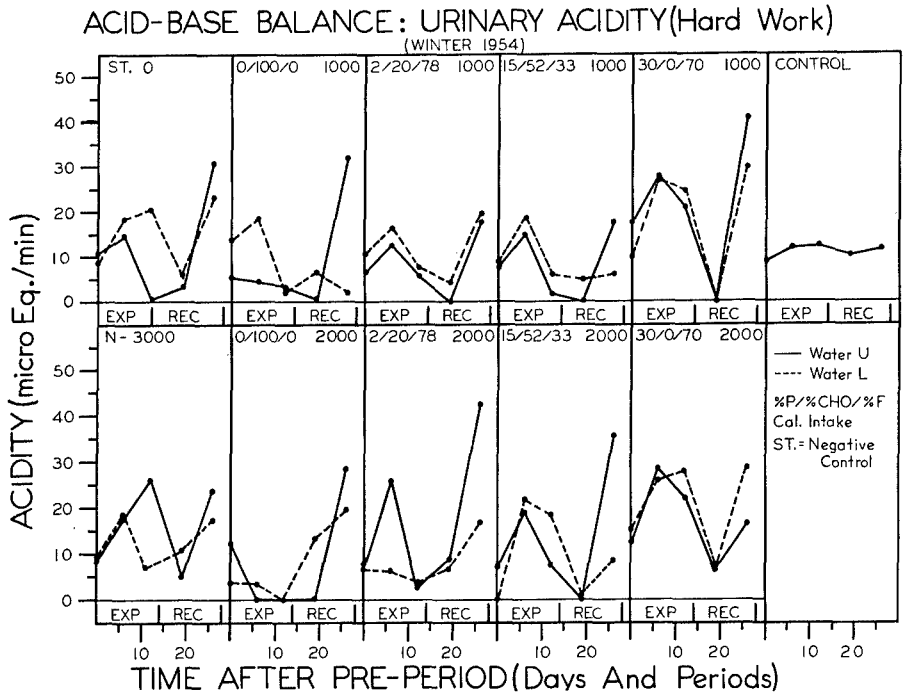

FIGURE III. 51. ACID-BASE BALANCE: URINARY ACIDITY (HARD WORK), WINTER, 1954.

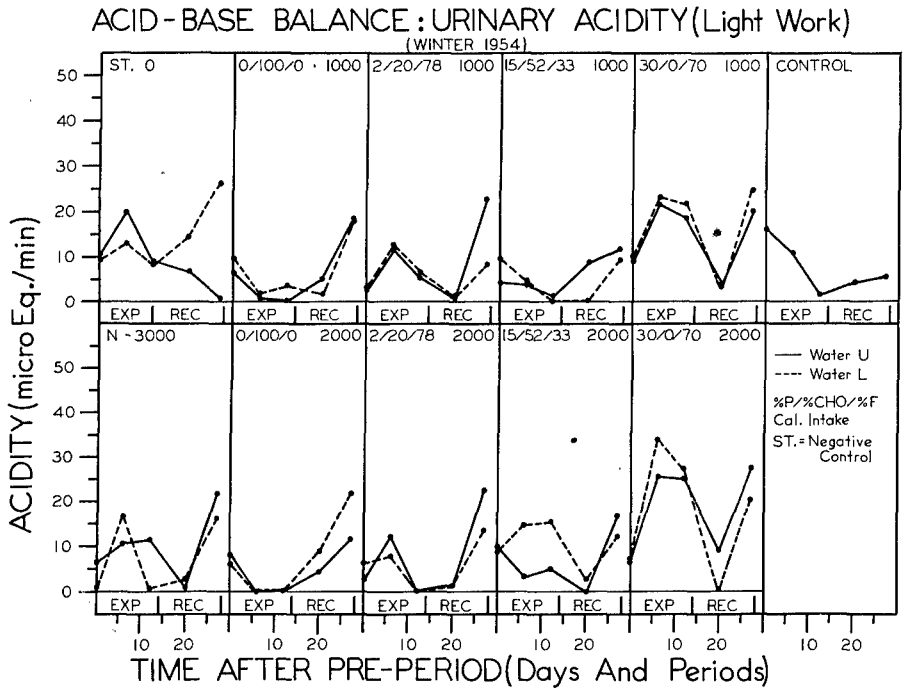

FIGURE III. 52. ACID-BASE BALANCE: URINARY ACIDITY (LIGHT WORK), WINTER, 1954.

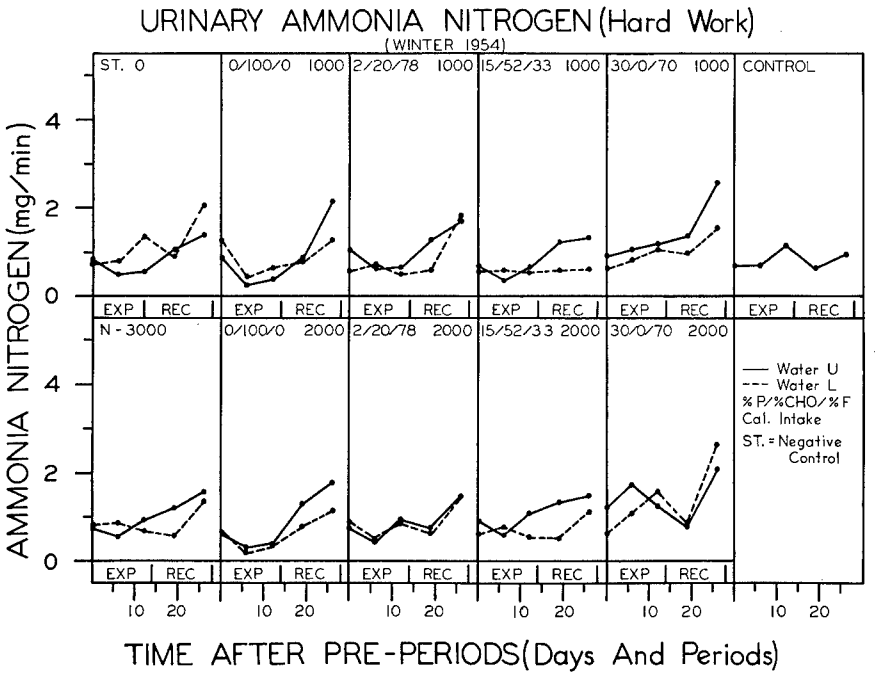

FIGURE III. 53. URINARY AMMONIA NITROGEN (HARD WORK), WINTER, 1954.

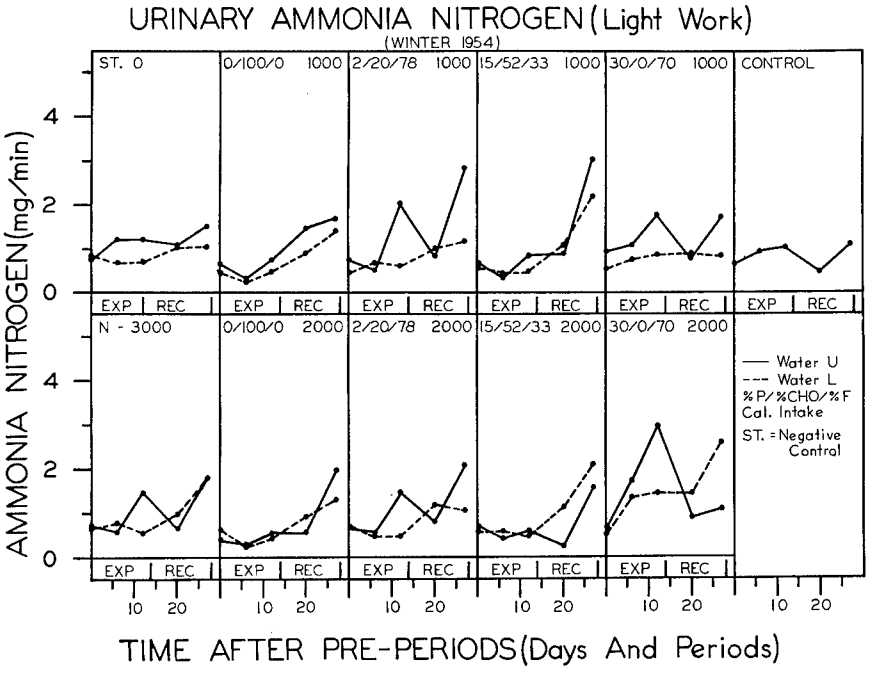

FIGURE III. 54. URINARY AMMONIA NITROGEN (LIGHT WORK), WINTER, 1954.

10. Carbohydrate And Fat Intakes

Carbohydrate and fat, together with protein, are the sources of energy in any diet. It is virtually impossible to estimate true balances of these two non-protein nutrients, and their turnover is very difficult to measure in man. Nevertheless, it is highly important to glean as much information as possible on their metabolism. The present section deals exclusively with intakes. Studies of blood glucose and fecal fat will be found elsewhere in this report.

Carbohydrate. Pre-period: A carbohydrate intake in the general range 320 to 600 gm/day was estimated in P I, the average being about 480 (Table III. 166). IN P II, there was a slight decrease in 33 of the 40 subject subgroups. During this period it will be recalled that the subjects were on 5-in-1 ration.

Experimental period: In order to provide the desired regimens, carbohydrate intake ranged from zero to 500 gm/day in different groups. Starvation and 30/0/70 provided no carbohydrate; 0/100/0 provided pure carbohydrate; and other regimens were intermediate (Table III. 166). There was no free choice on the part of any subject, and therefore no effect of environment should be expected.

Recovery period: During the first week of recovery, controlled rehabilitation was enforced for three days, after which the subjects had virtually free choice of items in the 5-in-1 ration. Their carbohydrate intakes exceeded P II substantially in all 40 subgroups except in the two subjects who had been on 15/52/33 U Hard Work (Table III. 166). Limitation of water in EXP II was correlated with a smaller carbohydrate intake in REC I in 14 of the 20 paired comparisons.

In REC II there was a further increase of carbohydrate intake in 39 of 40 subgroups. All nutrient intakes were high in REC II.

Fat. Pre-period: The intake of fat in the first week of pre-period was about 100 gm/day, the range being 84 to 150. During P II there was a decreased intake of 10 to 15 gm in 35 of the 40 subgroups (Table III. 167). These intakes are normal for young men, as is the variability.

Experimental period: Experimental regimens were rigidly controlled so that the fat intake was different in the different diets, ranging from 0 in starvation and 0/100/0 to 179 in 2/20/78 (Table III. 167). No free choice was allowed during these two weeks. Every subject was expected to eat everything he was given.

Recovery period: During the first week of recovery, almost free choice of 5-in-1 items was allowed in the last three days. The weekly average intake for REC I was greater than P II in all subgroups by amounts ranging from 20 to 60 gm. In REC II there was a further very substantial increase when dairy products, fresh meat, and butter were present in almost unlimited amounts. The largest fat intake in REC II was 362 gm/day (Table III. 167). As was true of carbohydrate, limitation of water in EXP II was correlated with a smaller fat intake in 15 of the 20 paired comparisons.

Voluntary Consumption of Carbohydrate and Fat in Recovery. We sought to check two observations that were made in the 1953 temperate study concerning carbohydrate intake in recovery, and one on fat:

a) As judged by recovery intakes, when the experimental intake had been 2000 Calories or more there was little "carbohydrate craving".

b) After 1000 Calories or less in experimental periods, there developed a "carbohydrate craving" if the carbohydrate allowance had been 50 gm or less but not if it had been 130 gm or over.

c) Fat craving appeared in recovery following acute calorie deprivation combined with a low percentage of calories in carbohydrate.

The data for the cold weather study of 1954 have been tabulated (Table III. 168) so as to facilitate inspection in the light of the above three observations of 1953. Averages were computed for all subjects regardless of water limitation in EXP II (although there was some influence of water limitation); P I and P II were averaged together; and in REC I only the last four days were averaged, because this was the time when the subjects had essentially free choice. The following conclusions may be drawn on the basis of an average rank ordering for all regimens in hard and light work in both weeks of recovery:

a) "Carbohydrate craving" did not appear in subjects whose experimental period intakes were 2000 Calories or more. This observation confirms 1953's.

b) After 1000 Calories in EXP II, or less, the order of carbohydrate intake was ST 0, 30/0/70 1000, 0/100/0 1000, 2/20/78 1000. There was no carbohydrate craving after 15/52/33 1000. Except for the anomalous position of 0/100/0, this list is the same as for 1953. That is to say, severe calorie deprivation combined with a low intake of carbohydrate leads to "carbohydrate craving" in recovery.

c) So far as fat intake was concerned, 1953 and 1954 agreed in the main conclusion: Fat craving was noticeable in REC II in subjects whose experimental regimens had been low in calories and low in carbohydrate (2/20/78 1000 and 30/0/70 1000).

It would appear that when the carbohydrate in a very low calorie regimen falls far below the normal balance of protein/fat/carbohydrate, one is likely to observe both carbohydrate and fat cravings in recovery. The physiological meaning of this very interesting phenomenon is quite obscure. Certainly it does not support the view that there is a specific "fat craving" in cold climates among working men.

TABLE III. 166

CARBOHYDRATE INTAKE
(gm/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	382	371	0	0	622	727	459	381	0	0	502	782
	L	493	475	0	0	634	764	461	407	0	0	548	608
0/100/0	U	460	350	252	246	684	689	469	428	248	243	516	852
1000	L	506	494	280	291	588	632	456	427	252	252	522	608
0/100/0	U	452	442	503	482	707	753	551	472	490	473	573	634
2000	L	480	400	504	504	522	589	430	396	504	504	530	576
2/20/78	U	611	441	46	46	582	700	274	426	45	46	576	714
1000	L	412	367	46	46	476	765	454	420	46	46	504	590
2/20/78	U	567	484	94	94	602	562	551	562	89	94	712	818
2000	L	471	450	94	94	539	663	509	428	94	94	597	640
15/52/33	U	488	437	166	166	651	664	483	447	166	166	548	678
1000	L	483	450	166	166	578	668	414	377	166	166	494	539
15/52/33	U	379	454	265	265	618	650	523	465	265	265	507	586
2000	L	434	444	265	265	501	782	418	398	265	265	437	557
15/52/33	U	492	413	397	397	380	546	452	406	397	397	559	708
3000	L	442	444	397	378	474	586	418	391	397	397	460	527
30/0/70	U	322	383	0	0	654	758	504	451	0	0	640	755
1000	L	546	509	0	0	592	706	437	391	0	0	534	608
30/0/70	U	383	321	0	0	526	548	390	430	0	0	528	604
2000	L	377	362	0	0	597	755	445	360	0	0	548	573

TABLE III. 167

FAT INTAKE
(gm/day)

Experimental Regimen		Hard Work						Light Work					
		Pre		Exp		Rec		Pre		Exp		Rec	
		I	II	I	II	I	II	I	II	I	II	I	II
ST 0	U	126	110	0	0	174	316	124	114	0	0	168	287
	L	125	114	0	0	170	311	127	108	0	0	180	245
0/100/0	U	125	101	0	0	182	309	124	115	0	0	158	283
1000	L	132	125	0	0	166	280	108	100	0	0	166	227
0/100/0	U	126	104	0	0	191	297	107	96	0	0	160	268
2000	L	118	90	0	0	135	250	129	114	0	0	172	252
2/20/78	U	150	115	89	89	185	317	68	110	86	89	170	296
1000	L	102	95	89	89	140	340	127	108	89	89	158	260
2/20/78	U	145	131	179	179	179	274	110	139	162	179	196	306
2000	L	138	130	179	179	164	302	130	125	179	179	180	265
15/52/33	U	130	100	38	38	201	333	140	130	38	38	178	318
1000	L	128	112	38	38	152	267	125	112	38	38	151	215
15/52/33	U	95	105	76	76	173	276	134	128	76	76	164	232
2000	L	119	137	76	76	161	280	116	97	76	76	133	234
15/52/33	U	142	112	114	114	146	242	130	127	116	114	184	293
3000	L	132	126	114	112	136	236	128	114	114	114	155	219
30/0/70	U	87	90	74	75	182	324	138	118	72	77	184	320
1000	L	127	102	75	75	156	284	116	108	75	79	162	274
30/0/70	U	110	84	147	151	140	265	114	113	146	147	167	240
2000	L	123	115	117	149	182	362	116	106	151	142	168	240

TABLE III. 168

VOLUNTARY CONSUMPTION OF CARBOHYDRATE AND FAT IN RECOVERY
(gm/day)

Experimental Regimen	Carbohydrate										Fat									
	Hard Work					Light Work					Hard Work					Light Work				
	PI&II	Rec I*		Rec II		PI&II	Rec I*		Rec II		PI&II	Rec I*		Rec II		PI&II	Rec I*		Rec II	
	In.	In.	Δ**	In.	Δ**	In.	In.	Δ**	In.	Δ**	In.	In.	Δ**	In.	Δ**	In.	In.	Δ**	In.	Δ**
ST C	430	811	381	746	316	427	668	241	695	268	119	227	108	314	195	118	239	121	266	148
0/100/0 1000	452	788	336	660	208	445	692	247	730	285	121	230	109	294	173	112	220	108	255	143
0/100/0 2000	444	748	304	671	227	462	650	188	605	143	110	208	98	274	164	112	204	92	260	148
2/20/78 1000	458	625	167	732	274	394	663	269	652	258	116	214	98	328	212	103	219	116	278	175
2/20/78 2000	493	645	152	612	119	512	803	291	729	217	136	174	38	288	152	126	196	70	286	160
15/52/33 1000	464	760	296	666	202	430	643	213	608	178	118	193	75	300	182	127	172	45	266	139
15/52/33 2000	428	674	246	716	288	451	554	103	572	121	114	212	98	278	164	119	183	64	233	114
15/52/33 3000	448	469	21	566	118	417	552	135	618	201	128	164	36	239	111	124	208	84	256	132
30/0/70 1000	440	769	329	732	292	446	736	290	682	236	102	225	123	304	202	120	231	111	297	177
30/0/70 2000	361	621	260	652	291	406	605	199	588	182	108	199	91	314	206	112	209	97	240	128
Mean, all subjects	442	691	249	675	233	439	657	218	648	209	117	205	88	293	176	117	208	91	264	147

*Days 4-7, Rec I.
**Increment of Rec I or Rec II over P I & II.

G. PHYSICAL FITNESS

The times of the physical fitness tests have been summarized in Table III. 169. In this table are shown (1) the mean pre-period times and (2) the mean change (in seconds) between pre-period and experimental period and between pre-period and recovery period. The mean times for the four flights were 3:47, 3:38, 3:50, and 4:01, respectively. In the pre-period only two men failed to complete the half-mile course. (Nos. 58 and 63). These men ran one lap (0.25 mile). Their times have been doubled and included in the average data. In the experimental period, five men did not perform the test: Nos. 1, 4, 47, 60, and 68. These were the subjects taken off diets early. The mean changes in times for the four flights were: +18, +8, +42, and +20 seconds, respectively. On the average, the times increased. In the recovery period all men took part in the test. The mean changes in times for the four flights were: +16, +13, +15, and +27 seconds, respectively. It is, therefore, evident that training effects were not important.

The striking differences in increments during the experimental period reflect the motivating factors discussed in Section II. Although all flights, on the average, took longer to perform the test, Flight 2 changed the least and Flight 3 the most. Flight 2 had a very high team spirit and was out to win the meet. Flight 3, in contrast, had relatively less team spirit and an attitude of merely having to "get it over with". In the recovery period the increments were more uniform. All flights lacked in spirit. Although there was some improvement over the larger increments of the experimental period, the times averaged longer than in the pre-period.

Analysis of the data reveals that the increments presented in Table III. 169 did not discriminate among the several conditions of the trial: work load, water intake, caloric intake, and distribution of calories. The fact that all men were able to complete the half mile course is in itself the most significant finding of all. Even after seven days of starvation some of the subjects actually ran faster than they did during the pre-period. Such men, in spite of obvious clinical deterioration, were sufficiently motivated to overcome their handicap and accomplish a trying task.

Some information on the fastest and slowest times in each of the three tests is given in Table III. 170.

The pulse rates measured after the half-mile run did not, on the average, vary appreciably (Table III. 171). Their magnitude represents the fact that the task was moderately difficult and that the men made an effort to perform the job. The pulse rates, like the time-increments do not discriminate between the diets. It was thought that the slow pulse rates frequently observed in the experimental period among men subsisting on low calorie regimens might be a reflection of the characteristic bradycardia of undernutrition. This reduction of the pulse rate was especially evident among men on limited water who were doing hard work: 0/100/0 1000, 2/20/78 1000, 15/52/33 2000, and 30/0/70 1000 and 2000. Examination of the resting versus post-work pulse rates, however, failed to reveal any consistent correlation.

TABLE III. 169

PHYSICAL FITNESS: TIME TO RUN HALF MILE

Experimental Regimen		Hard Work Pre t min:sec	Hard Work Exp Δt sec	Hard Work Rec Δt sec	Light Work Pre t min:sec	Light Work Exp Δt sec	Light Work Rec Δt sec
ST 0	U	4:14	-21	-22	3:54	+171	+ 13
	L	3:41	+23	+14	4:03	+104	- 16
0/100/0	U	3:43	+35	- 1	3:50	+ 15	+ 7
1000	L	3:56	-17	+15	4:00	+ 50	+ 18
0/100/0	U	3:19	+ 9	+20	3:37	+ 28	- 1
2000	L	3:26	- 9	+21	4:40	- 46	+ 30
2/20/78	U	3:19	+32	+24	4:34	+ 26	+ 16
1000	L	3:44	-12	0	3:24	+ 8	+ 14
2/20/78	U	3:49	+29	+22	4:05	+ 33	- 17
2000	L	3:19	+40	- 2	3:54	+ 10	- 14
15/52/33	U	3:53	+14	+37	3:36	0	+ 45
1000	L	4:07	-18	+ 4	3:48	+ 19	+ 30
15/52/33	U	3:20	+18	+34	3:53	+ 56	0
2000	L	3:38	+12	+ 2	4:00	+ 18	+ 22
15/52/33	U	3:58	-22	+10	3:23	+ 8	- 9
3000	L	3:20	+ 8	+12	3:21	+ 16	+ 74
30/0/70	U	3:52	+70	+67	3:52	+ 40	+ 56
1000	L	3:48	+18	+39	4:46	- 12	+ 29
30/0/70	U	4:02	+11	+14	3:43	+ 38	+ 39
2000	L	3:25	+20	+26	3:57	+ 40	+104
Mean, all subjects	U	3:47	+18	+16	3:50	+ 42	+ 15
	L	3:38	+ 8	+13	4:01	+ 20	+ 27

TABLE III. 170

SOME STATISTICS ON HALF MILE RUN

Condition	Pre	Exp	Rec
Fastest time, min:sec	3:11	3:06	2:48
Subject code number	14,15	30	68
Experimental nutrient mixture	----	0/100/0 2000 L	----
Slowest time, min:sec	5:35	7:51	6:22
Subject code number	74	46	76
Experimental nutrient mixture	----	ST 0 U	----

TABLE III. 171

PHYSICAL FITNESS: PULSE RATE AFTER HALF MILE RUN

Experimental Regimen		Hard Work			Light Work		
		Pre	Exp	Rec	Pre	Exp	Rec
ST 0	U	138	144	153	131	100	143
	L	154	146	156	135	136	152
0/100/0	U	139	152	150	138	166	134
1000	L	162	126	140	168	137	161
0/100/0	U	150	158	166	128	146	159
2000	L	162	163	156	149	132	120
2/20/78	U	142	140	166	137	133	163
1000	L	168	128	151	144	152	134
2/20/78	U	180	156	154	128	144	148
2000	L	159	164	161	141	175	160
15/52/33	U	135	138	150	120	156	139
1000	L	162	162	157	150	136	156
15/52/33	U	165	164	154	125	145	128
2000	L	162	126	176	150	155	142
15/52/33	U	156	160	150	138	156	168
3000	L	169	172	162	150	158	148
30/0/70	U	148	158	140	122	154	140
1000	L	156	142	136	136	150	136
30/0/70	U	152	167	157	118	134	148
2000	L	158	146	151	165	138	146
Mean, all	U	148	154	154	128	144	146
subjects	L	161	148	155	148	147	146

H. CLINICAL EVALUATION OF NUTRIENT COMBINATIONS

The overall clinical impression gained from daily observations of the subjects during the two-week period at Camp McCoy was that a surprisingly few men developed marked overt deterioration. Furthermore, there were very few well-developed syndromes. Careful scrutiny of the medical records, however, definitely established the fact that functional disturbances described were conditioning the behavior of the subjects. A classification of the spontaneous and elicited complaints of the subjects is given in Table III. 172. This classification is admittedly crude, but for present purposes it will serve.

The number of men complaining of each symptoms within these five groups of system complaints was summed for each of the several experimental regimens. An analysis of these sums is given in Table III. 173. In those cases where groups contained more than two men, the sums were adjusted to approximate number per two men. A number of significant observations may be made on the basis of data within this table.

1. Systemic Complaints

Gastrointestinal Complaints. Symptoms referable to dysfunction of the gastrointestinal system were the most common of the five groups. On the 2000-

and 3000-Calorie regimens there was a tendency for the number to increase with limitation of water. At the 1000-Calorie level water intake had no consistent effect. Of special interest is the fact that the number of complaints per subject did not change appreciably with variations in total caloric intake (Table III. 174). The most striking observation relative to nutrient mixture is the rather consistent high incidence among men on the high fat regimens (70 and 78% fat).

Central Nervous Complaints. Symptoms referable to functional changes in the central nervous systems were not accentuated by limitation of water but they were markedly increased by reduction in the caloric intake (Table III. 174). Again, it is evident that the high fat diets are the regimens generally correlated with higher incidence of such complaints. Certainly those clinical observations are consistent with the hypoglycemia which was detected in blood from men subsisting on the 30/0/70 and 2/20/78 nutrient mixtures. Actually the surprising fact is that no subject developed a clear hypoglycemic syndrome. The above findings suggest that a sub-clinical condition was present. Why it never materialized into a full-blown episode is a question difficult to answer satisfactorily.

TABLE III. 172

CLASSIFICATION OF COMPLAINTS BY SYSTEMS

Gastrointestinal System	Central Nervous System
1. Anorexia	1. Weakness
2. Hunger	2. Lethargy
3. Nausea	3. Light headedness
4. Vomiting	4. Fainting
5. Gagging	5. Blackout spells
6. Heartburn	6. Insomnia
7. Gas	7. Sleepiness
8. Abdominal cramps	8. Headache
9. Loose stools	9. Chilliness
10. Frequent stools	10. Anxiety
11. Constipation	11. Euphoria
12. No bowel movements	12. Aphonia (hysterical)
13. Burning anus	13. Nightmares
14. Hemorrhoids	
Oral Complaints	**Neuromuscular System**
1. Dry mouth	1. Muscle cramps
2. Sore mouth	2. Joint pain
3. Sore tongue	3. Sore feet
4. Cracked lips	4. Burning feet
5. Thirst	5. Numbness
6. Change in taste	6. Tingling
	7. Parethesia
Miscellaneous	
1. Sore throat	
2. Toothache	
3. Cough	
4. Chest pain	

TABLE III. 173

ANALYSIS OF SYSTEM COMPLAINTS
(number/two subjects)

System Complaints and Experimental Regimen	N		3000		30/0/70		2000		15/52/33		2000		2/20/78		2000		0/100/0		2000		30/0/70		1000		15/52/33		1000		2/20/78		1000		0/100/0		1000		ST		0	
	U		L		U		L		U		L		U		L		U		L		U		L		U		L		U		L		U		L		U		L	
Gastrointestinal																																								
Hard work	0		2		2		6		5		5		1		4		1		2		6		5		2		3		3		5		6		2		(3)		(4)	
Light work	1		12		11		12		5		8		(11)*		14		5		8		10		7		8		5		7		5		9		11		(7)		(11)	
Central nervous																																								
Hard work	0		2		0		2		2		0		1		0		2		1		9		2		4		2		8		4		4		2		(4)		(6)	
Light work	0		4		8		4		0		2		(7)		4		5		2		10		5		9		2		12		5		7		3		(13)		(11)	
Neuromuscular																																								
Hard work	1		0		0		1		0		0		0		0		2		0		0		1		0		2		1		2		3		2		(1)		0	
Light work	2		1		0		5		0		1		0		2		0		1		2		4		0		1		0		2		0		1		(5)		(5)	
Oral																																								
Hard work	0		0		0		2		0		0		0		0		0		0		0		2		0		0		0		0		1		0		0		(4)	
Light work	0		3		2		4		0		1		0		4		0		0		1		4		0		0		1		4		2		2		(1)		(5)	
Miscellaneous																																								
Hard work	2		0		1		0		2		0		0		0		0		0		0		0		1		1		0		0		0		1		(1)		0	
Light work	1		2		1		1		1		3		(1)		2		0		3		2		2		0		1		1		2		2		0		(1)		(3)	
Total																																								
Hard work	3		4		3		11		9		5		2		4		4		3		15		10		7		8		12		11		14		7		9		14	
Light work	4		22		22		26		6		15		19		26		10		14		25		22		17		9		21		18		20		17		27		35	
Water	7		26		25		37		15		20		21		30		14		17		40		32		24		17		33		29		34		24		36		49	
Nutrient regimen	33				62				35				51				31				72				41				62				58				85			

*Values in parentheses adjusted to number of complaints/two subjects.

Neuromuscular Complaints. Here we deal with a group of symptoms which, although less numerous than those referable to the central nervous system, neverthless, show much the same trends. A lower caloric intake was associated with an increase in the number of complaints (Table III. 174) and the high fat regimens tended to be the ones with the greatest number of complaints.

Oral Complaints. These symptoms could be attributed generally to dehydration. The complaints were consistently more common among men on limited water than among those on unlimited water. Starvation and the high fat regimens were the nutrient mixtures associated with greatest number of complaints.

TABLE III. 174

SYSTEM COMPLAINTS VS. CALORIC INTAKE
(complaints/subject)

System Complaints	Caloric Intake, Cal/day 3000	2000	1000	0
Gastrointestinal	1.9	3.2	2.9	3.0
Central Nervous	0.8	1.3	2.7	3.9
Neuromuscular	0.5	0.4	0.7	1.1

2. General Remarks

Work Load. In general there were many more system complaints among the subjects performing light work than among those performing hard work. The inverse might have been expected. On the other hand, the sedentary groups may have had more symptoms merely because they were less busy and consequently they had more time for introspection.

Water Intake. When the total symptoms for the five categories of symptom complaints and two levels of work output are summed, it is at once evident that limitation of water augments symptom-frequency at all caloric levels except 1000 Cal/day. In general the difference in symptom frequency between the "U" and "L" regimens was greatest among those diets providing high solute loads: N-3000, 30/0/70, and 2/20/78. When the solute load was low, limitation of water had much less effect: 15/52/33 and 0/100/0. These trends indicate that the striking biochemical and functional correlates of chronic dehydration were probably leading to incipient deterioration in behavior. Certainly it would be reasonable to predict that very little additional stress of such castaways would rapidly lead to marked deterioration in the survival potential. Such stresses might be (1) colder weather, (2) inadequate environment protection (clothing, shelter), (3) demand for greater energy expenditure (escape over rough terrain or through deep snow or boggy ground), (4) greater restriction of available water, and (5) injury.

Nutrient Regimen. When the symptoms are summed according to nutrient mixture, it is evident that starvation is the worst possible regimen. High fat regimens are next most productive of symptoms and reduction of caloric intake augments the incidence. At 1000 Cal/day, the 0/100/0 diet is almost as provocative of symptoms as the 2/20/78 regimen. At 1000 Cal/day 15/52/33

caused the fewest number of symptoms. At 2000 Cal/day 0/100/0 and 15/52/33 were almost equal in producing symptoms and were the least provocative of the regimens. N 3000 U was by far the best nutrient combination in this respect.

The most significant generalization which can be made from these data is that marked deviations from the 15/52/33 distribution of calories regularly lead to an increase in complaints. The complaints are most regularly augmented when the fat content is increased. A similar trend is evident for protein when the fat content is high and the carbohydrate low. An all-carbohydrate regimen is apparently clinically debilitating only when there is marked restriction of calories. These clinical findings are supported by the biochemical and functional data discussed earlier. They lead to the conclusion that the 15/52/33 regimen has a basic physiological import. The questions which come to mind are: (a) What has been the evolutionary origin of this distribution? (b) Why is physiological economy greatest when the organism subsists on such a regimen? (c) Does a self-selected diet have a similar distribution? (d) Do natural deviations from this ratio lead to functional disturbances or account for morphological and functional differences between national groups?

3. Rehabilitation

In contrast to the 1953 temperate study, recovery in 1954 was controlled and as a consequence there was a much lower incidence of "post-period blues" -- abdominal fullness, abdominal cramps, nausea, vomiting, and diarrhea, and general malaise. During the first three days of REC I, caloric intake was restricted. There were no significant complaints. On the fourth day, ad libitum feeding began and at time of the mid-day meal there occurred some dozen episodes of acute vomiting. Many other subjects complained of abdominal fullness and abdominal cramps. Within 24 hours all of these complaints had disappeared and the remainder of REC I was uneventful. It is noteworthy that when the subjects began eating the garrison ration in REC II, there were no further episodes of gastrointestinal symptoms. At this time, however, a number of the men complained of urinary frequency and polyuria. This condition subsided within 48 hours, and for the remainder of REC II there were no further clinically significant complaints.

SECTION IV

DISCUSSION: TABLE OF CONTENTS

A. INTRODUCTION

The purpose of this discussion is to attempt to judge the relative merits of 20 combinations of protein, carbohydrate, fat, calories, and water used both in hard work and in light work as described in Sections II and III. Our attention will be centered on the single practical question: Is it possible from our data to settle upon an optimal combination as a potential all-purpose survival ration? We shall also discuss five generalizations of major theoretical importance which can be made from the experiences and observations of 1953 and 1954:

a) The concept of the balanced diet.
b) Minimum nutritional requirements.
c) The catabolic reaction in the castaway.
d) Interrelations among osmotic load, body water, and renal function.
e) Limits of homeostasis.

B. THE OPTIMAL NUTRIENT COMBINATION FOR SURVIVAL IN THE COLD

In order to make adequate judgements, logical criteria must be established. Among the many measurements which were made in this study, 21 proved to be discriminatory among the several nutrient combinations, could be quantitatively expressed, and could be logically related to maintenance or deterioration of the survival potential of the castaway. Other quantitative measurements could

not be so used, either because they were not discriminatory among nutrient combinations, or because they were autocorrelated with other discriminatory measures, or because they have not been proved to be predictive of potential damage.

Perhaps more important than these quantitative tests were the clinical observations of the subjects' symptoms and the objective signs of deterioration. The reason why clinical observations must be considered highly significant is that deterioration in the body as a whole may give rise to detectable signs and symptoms before there are measurable physiological and biochemical deviations from normal. Only one truly serious defect in an otherwise perfect ration could lead to fatal deterioration in a survivor. For example, the incapacitating nausea and excruciating headache frequently caused by the pre-World War II "D Bar" were evoked in the absence of demonstrable biochemical lesions (D.B. Dill, personal communication). This concept of the "weakest link" in an otherwise superior survival ration must be emphasized in any statistical consideration of the various survival rations. It is quite possible that only on clinical grounds can the "weakest link" be detected. In any case, clinical observations must be considered together with the biochemical and physiological data.

1. Biochemical and Physiological Ratings

All biochemical and physiological measurements have been summarized in a fashion permitting rank-order treatment. For final compilation 21 measurements were tabulated (Tables IV. 1 and 2); all were logically related to survival potential. Defense of this selection is needed only in general terms. Negative balances of calories, water, nitrogen, chloride, sodium, and potassium will lead sooner or later to deterioration. Until proved otherwise, ketonuria must be considered deleterious or at least wasteful of energy. Minimal decreases in body weight and body water (as measured by D_2O space and water diuresis test) must be considered advantageous in survival. Normal functioning of the liver is important; in our study it seemed to be best correlated with serum cholinesterase. Normal kidney function is critical in survival. Creatinine clearance and serum non-protein nitrogen are currently the most popular measures among clinical investigators of renal function. The osmotic parameters (minimal obligatory urine volume and the U/S osmotic ratio) have been discussed fully in Section III; for present purposes mean urine volume and calculated U/S ratios have been used. The Addis count is a quantitative measure of formed elements in the urine which must be considered, when present in abnormal numbers, as evidence of actual or potential tissue damage. Of the three endocrine functions listed, the 17-ketosteroids are associated with adrenocortical function, the blood sugar with pancreatic and pituitary function among other relations, and the serum chloride probably with adrenocortical function although it is also influenced by gross changes in dietary intake.

Biochemical and physiological ratings have been made for both work regimens so that it would be possible to determine whether work load had any appreciable influence on the rank-order of the 20 nutrient regimens.

In setting up Tables IV. 1 and 2, in general, mean values for all nutrient combinations during the second experimental week were assigned rank-order numbers ranging from one to 20. Exceptions were made for creatinine clearance, blood sugar, serum cholinesterase and serum amylase for which the lowest values during experimental or recovery periods were considered to be more significant than the mean value of the second experimental week. In the Addis counts for casts and red cells and in ketonuria, many values of zero were obtained which necessitated assigning to each zero the median value for the series of zeros. The sum of each of the 21 rank-order numbers for each nutrient combination was calculated. In every case the lowest rank-order number is considered to represent the best effect of the nutrient combination. Therefore, the sum of all the rank-order numbers represents a composite score in which 21 would be perfect and 420 would be worst. For ease of interpretation, the data in Table IV. 1 and 2 have been consolidated in Table IV. 3 and Figures IV. 1 and 2 which show for each nutrient combination the rank-order scores as they fell into four quartiles, the best being the first quartile (1-5) and the worst being the fourth quartile (16-21).

Before attempting to discuss Tables IV. 1 and 2 and Figures IV. 1 and 2, it will be necessary for us to list quantitative measurements which were not considered pertinent for the present purpose for one or another of four main reasons (Table IV. 4). These reasons are: (a) The changes in quantities were so small that an attempt to rank-order the several regimens was absurd. (b) It was our conviction that the measurements had no relation to the survival potential as currently conceived by the USAF; viz., ability of the castaway to withstand the stresses of survival for not more than 10 to 14 days. (c) The data were incomplete or technically unreliable. (d) An additional group of measurements was omitted so as not to weight by autocorrelation the average rank-order. Among these were:

Measurement	Autocorrelated with
Minute urinary volume	24-hr urinary volume
Albuminuria; white blood cells and epithelial cells in urine	Addis count: red cells and casts
Serum osmolarity, urinary osmotic excretion, and osmolar clearance	U/S osmotic ratio
Serum creatinine	Serum non-protein nitrogen
Minute urinary creatinine	Creatinine clearance
Urinary pH, titrable acidity, and ammonia nitrogen	Ketonuria

General interpretations of the quantitative biochemical and physiological measurements should be made by examination of Table IV. 5 in conjunction with Figures IV. 1 and 2. Four major conclusions are supported by the data relative to the hard work group. First, with unlimited water, no nutrient combination ranked as high as the positive control at 3000 Cal/day or as low as starvation. Second, with limited water only two combinations, 0/100/0 and 2/20/78 2000, ranked close to the positive control, with 15/52/33 not far behind; and none was as bad as starvation. Third, regardless of water intake, no nutrient combination at 1000 Cal/day ranked as high as the same nutrient combination at

2000 Cal/day. Fourth, water restriction worsened the score of every nutrient combination except the low osmotic regimens -- 0/100/0 2000, 0/100/0 1000, and 2/20/78 1000.

Turning to the light work groups, four major conclusions similar to those for hard work may be drawn. First, with unlimited water one regimen, 15/52/33 2000, was close to the positive control and one regimen, 30/0/70 1000, was as bad as starvation. Second, when water intake was limited no regimen was as good as the positive control or as bad as starvation. Third, regardless of water intake, nutrient regimens at 2000 Cal/day scored better than they did at 1000 Cal/day except 15/52/33. Fourth, with no exceptions limitation of water worsened the score of every nutrient combination -- even in the cases of the low osmotic regimens.

It is evident that the general conclusions are the same for hard and light work. Increasing the caloric intake improves the score of a given nutrient combination and restriction of water makes the score worse. Of the 2000-Calorie regimens 15/52/33 was far the best when water was unrestricted; with limited water 2/20/78 was best followed closely by 15/52/33 and 0/100/0. Of the 1000-Calorie regimens 15/52/33 was far the best regardless of water intake.

2. Clinical Interpretations

The final decisions among these "best" nutrient combinations must be made on clinical grounds for all had defects which might be due to the action of the "weakest link".

The data on clinical findings have been discussed in Section III and have been summarized in Table IV. 6. Four major conclusions can be drawn. First, with unlimited water no experimental regimen produced as few symptoms as the positive control or as many as starvation. Second, with limited intake of water, the fewest symptoms were provoked by 0/100/0 2000 and 15/52/33 1000; the most by starvation. Third, for any given regimen addition of calories reduced the incidence of symptoms when water was unlimited, but accentuated symptomatology in all but the lowest solute regimen, 0/100/0. Fourth, for any given regimen, limitation of water increased symptoms when the solute load was high or intermediate (N-3000, 30/0/70 2000, 15/52/33 2000, 2/20/78 2000, and ST 0) and had little effect or even decreased symptoms when the osmotic load was reduced (0/100/0 2000, 0/100/0 1000, 30/0/70 1000, 15/52/33 1000, and 2/20/78 1000).

Considering the clinical studies as a whole and the incidence of system complaints, the best regimens were N-3000, 15/52/33 2000, and 0/100/0 2000, whereas starvation was by far the worst.

3. General Remarks

In arriving at a decision for the best nutrient regimen for survival in the cold, the generalizations should be drawn from the rank-order in the biochemical and physiological data and from the clinical observations. One important feature of the rank-ordering is in the distribution of scores by

quartiles (Figures IV. 1 and 2), for these distributions bring out strengths and weaknesses not fully apparent in a gross score (Table IV. 5). In the first quartile appear the best features and in the fourth quartile the worst. In fact numerous scores in the fourth quartile involve defects which could be very well classified as "weak links". Our final interpretation of the winter study of 1954 is based on a scrutiny of all the data in the light of the above considerations.

The temperate study of 1953 provided background data for studying the effects of cold and work on survival potential. To that end the 1953 control study was conducted in a metabolic ward on a small group of men. One general conclusion from that study was that, all things considered, the best formula for a survival ration was 2000 Calories of a mixture providing 15% of the calories in protein of good quality, 52% in carbohydrate, and 33% in fat. The general conclusion from the 1954 cold weather study is the same. This mixture both in hard work and light work was clearly superior to all of the other regimens investigated. The two other important conclusions of the 1953 study were confirmed by the present investigation; viz., that no 1000-Calorie regimen ranked as high as the same regimen at 2000 Calories and that water restriction was uniformly deleterious.

None of the nutrient combinations was without defect. Some of these were intrinsic, others were attributable to the actual food item with which we were provided. The former defects are not remediable technologically; the latter almost certainly are. An unexpected and previously neglected aspect of survival rations is the probable importance of their inorganic constituents in addition to protein, carbohydrate, and fat.

The most damaging intrinsic defects of 30/0/70 are a high osmotic load, production of hypoglycemia, and tendency to produce ketosis, nausea, and lassitude. In 2/20/78 the defects are tendency in all subjects to produce hypoglycemia, and in a few, production of nausea and other evidences of fat intolerance. In 0/100/0, in spite of many good qualities, there is a renal involvement with microscopic hematuria and cylindruria. In 15/52/33 the osmotic load in the 1954 study was high enough that limitation of water at 2000 Calories had some deleterious effects. This defect may be technologically soluble by providing low salt crackers.

To summarize this practical section, we recommend for cold or temperate climates a survival ration of 2000 Calories per day and a protein/carbohydrate/fat calorie ratio of 15/52/33. Such a ration can easily be provided in palatable form from meat bar, low salt crackers and other carbohydrates, dried fruits, and dried milk. Vitamin pills should be standard.

TABLE IV. 1
RANK-ORDER OF NUTRIENT COMBINATIONS: HARD WORK

Measurement (Second Week of Experimental Period or Lowest Value during Experimental or Recovery Periods.)	Nutrient Combination: N 3000		30/0/70 2000		15/52/33 2000		2/20/78 2000		0/100/0 2000		30/0/70 1000		15/52/33 1000		2/20/78 1000		0/100/0 1000		ISO	
	U	L	U	L	U	L	U	L	U	L	U	L	U	L	U	L	U	L	U	L
Body Composition																				
1. Body weight, least loss	1	4	6	10	2	18	8	15	7	11	3	16	5	13	13	8	13	17	19	20
2. Body water, least loss	4	15	1	20	3	12	2	9	5	18	6	12	7	17	8	16	10	14	11	19
3. Water diuresis test	3	16	4	18	8	19	2	15	10	8	11	20	9	17	1	14	6	12	13	4
Kidney Function																				
1. Osmotic parameters																				
a. Mean 24-hr urinary volume	13	10	18	12	15	8	20	5	7	2	17	9	19	6	16	4	14	1	11	3
b. U/S ratio	5	20	14	18	3	15	2	10	4	11	1	12	13	16	8	17	6	7	9	19
2. Creatinine clearance (EI)	12	2	1	7	4	5	10	8	19	18	16	10	9	6	3	20	16	18	14	13
3. Serum non-protein nitrogen	9	19	14	20	8	16	2	14	2	6	10	18	6	16	4	12	2	8	10	16
4. Addis count																				
a. Red blood cells	13	5	5	5	5	5	18	5	12	17	5	11	5	5	5	14	16	20	15	19
b. Casts	7	18	7	7	7	16	7	7	7	17	7	7	7	7	7	7	14	20	15	19
Endocrines																				
1. Blood sugar (EI)	2	6	20	17	11	13	6	7	16	2	19	18	9	14	14	2	11	4	8	11
2. 17-ketosteroids	3	4	6	6	2	8	11	15	17	2	18	18	14	9	11	14	11	7	20	16
3. Serum chloride, least change	10	10	7	4	10	14	1	4	10	16	20	4	14	4	17	4	18	10	19	10
Liver Function																				
1. Serum cholinesterase	5	3	9	4	1	6	6	2	16	12	10	16	18	13	16	8	19	12	20	16
Gastrointestinal Function																				
1. Serum amylase	1	10	13	10	11	2	8	18	2	16	16	5	6	14	19	12	4	7	20	15
Balances																				
1. Calorie	1	2	14	4	5	6	10	7	9	3	8	14	11	16	17	12	18	15	19	20
2. Water	1	11	5	20	4	15	12	13	7	3	2	19	7	15	17	9	10	7	15	18
3. Nitrogen	2	6	1	7	5	4	12	8	10	9	3	12	12	16	19	18	14	14	17	20
4. Chloride	16	17	19	20	18	14	3	1	8	6	10	16	5	2	9	13	4	7	12	11
5. Sodium	2	3	8	5	4	2	14	6	13	12	7	11	9	10	18	19	16	16	20	17
6. Potassium	5	12	1	2	6	4	18	13	17	6	3	10	20	12	15	15	20	8	15	8
7. Ketonuria (>+2, EII)	10	5	18	18	5	5	12	12	5	5	18	18	5	5	18	14	5	5	12	15
Total Score	125	198	191	234	137	207	184	194	203	200	210	276	210	233	255	252	247	229	314	309
General Rank	1	6	4	14	2	9	3	5	8	7	10	18	10	13	17	16	15	12	20	19

TABLE IV. 2
RANK-ORDER OF NUTRIENT COMBINATIONS: LIGHT WORK

Measurement (Second Week of Experimental Period or Lowest Value during Experimental or Recovery Periods.)	Nutrient Combination: N 3000		30/0/70 2000		15/52/33 2000		2/20/78 2000		0/100/0 2000		30/0/70 1000		15/52/33 1000		2/20/78 1000		0/100/0 1000		ISO	
	U	L	U	L	U	L	U	L	U	L	U	L	U	L	U	L	U	L	U	L
Body Composition																				
1. Body weight, least loss	1	3	2	14	7	4	10	10	11	8	18	16	6	4	13	12	16	15	20	19
2. Body water, least loss	2	16	9	17	2	10	3	18	8	14	7	15	5	12	6	11	14	20	4	20
3. Water diuresis, least change	5	20	4	18	12	20	7	16	15	8	8	18	9	6	3	1	11	14	10	13
Kidney Function																				
1. Osmotic parameters																				
a. Mean 24-hr urinary volume	15	7	19	14	12	8	20	5	13	2	16	10	11	3	17	1	9	4	18	6
b. U/S ratio	12	19	8	16	9	18	2	17	6	7	13	20	4	11	5	14	3	15	1	10
2. Creatinine clearance (EI)	3	9	10	4	1	7	5	18	8	19	2	12	16	20	6	16	16	12	11	16
3. Serum non-protein nitrogen	10	16	18	19	12	15	4	6	2	2	17	20	10	14	6	4	5	14	10	16
4. Addis count																				
a. Red blood cells	20	17	6	15	6	13	6	19	6	6	6	6	6	6	6	6	16	18	6	14
b. Casts	8	8	8	8	8	8	8	8	8	8	8	8	8	19	8	17	8	18	8	20
Endocrines																				
1. Blood sugar (EI)	1	6	6	17	10	10	12	19	3	2	15	16	11	8	18	20	4	4	12	14
2. 17-ketosteroids	3	2	12	8	4	2	5	10	14	14	16	12	6	7	9	19	20	13	18	16
3. Serum chloride, least change	13	16	20	6	2	18	6	6	6	10	16	2	10	10	6	6	10	14	18	14
Liver Function																				
1. Serum cholinesterase	3	4	18	6	2	16	1	8	6	15	14	20	9	13	7	11	12	10	16	19
Gastrointestinal Function																				
1. Serum amylase	9	1	15	16	4	3	17	10	6	13	12	18	8	14	4	20	7	12	2	18
Balances																				
1. Calories	2	1	5	3	10	4	9	6	6	8	18	14	11	12	17	16	13	15	20	19
2. Water	1	2	8	18	13	4	10	6	11	4	19	15	12	5	16	6	14	10	20	17
3. Nitrogen	2	1	5	7	3	5	8	9	13	12	17	19	10	5	14	16	11	16	18	20
4. Chloride	18	6	20	19	14	15	1	2	10	13	18	16	12	5	4	3	10	8	12	8
5. Sodium	2	1	10	5	4	3	20	13	19	11	6	16	7	8	18	17	10	12	14	15
6. Potassium	16	4	1	12	3	7	14	12	6	2	18	20	12	8	10	14	6	9	17	18
7. Ketonuria (>+2, EII)	5	5	18	12	5	5	13	12	5	5	18	14	5	5	18	18	5	5	18	18
Total Score	151	164	222	254	143	195	181	230	182	183	282	307	188	195	211	238	220	258	273	330
General Rank	2	3	12	15	1	9	4	13	5	6	18	19	7	8	10	14	11	16	17	20

TABLE IV. 3

RANK-ORDER QUARTILES: ALL REGIMENS

Experimental Regimen		Hard Work Quartile				Light Work Quartile			
		1	2	3	4	1	2	3	4
ST 0	U	0	3	9	9	3	4	4	10
	L	2	2	5	12	0	3	5	13
0/100/0	U	4	4	6	7	4	7	6	4
1000	L	3	8	5	5	3	4	10	4
0/100/0	U	5	9	2	5	3	11	6	1
2000	L	6	5	4	6	6	7	7	1
2/20/78	U	4	4	4	9	4	9	2	6
1000	L	3	4	9	5	4	3	5	9
2/20/78	U	6	7	5	3	7	8	3	3
2000	L	5	8	7	1	2	10	3	6
15/52/33	U	4	9	5	3	3	11	6	1
1000	L	4	5	6	6	6	7	6	2
15/52/33	U	12	5	3	1	10	6	5	0
2000	L	7	4	6	4	8	6	3	4
15/52/33	U	13	4	3	1	12	3	3	3
3000	L	8	5	3	5	10	5	1	5
30/0/70	U	6	7	1	7	1	5	4	11
1000	L	2	4	6	9	1	3	6	11
30/0/70	U	7	6	4	4	5	8	2	6
2000	L	6	6	1	8	3	5	5	8

TABLE IV. 4

MEASUREMENTS STUDIED AND NOT INCLUDED IN TABLE IV. 1
BECAUSE RELATION TO SURVIVAL POTENTIAL UNPROVEN

Quantities Unchanging During Experimental Period.	Quantities Teleologically Unrelated or Autocorrelated Regardless of Experimental Result.
Endocrines	Body Composition
1. Serum sodium	1. Body fat
2. Serum potassium	Renal Function
3. Serum calcium	1. Minute urinary volume
4. Serum inorganic phosphate	2. Albuminuria
5. Serum alkaline phosphatase	3. White blood cells
6. Minute urinary creatine	4. Epithelial cells
Liver Function	5. Serum osmolarity
1. Serum total cholesterol	6. Urinary osmotic excretion
Cardiovascular Function	7. Osmolar clearance
1. Resting blood pressure	8. Serum creatinine
2. Electrocardiogram	9. Minute urinary creatinine
Hematology	Gastrointestinal Function
1. Hematocrit	1. Fecal wet weight
	2. Fecal fat
	3. Occult blood
	4. Fecal muscle fibers
	Respiration Function
	1. Oxygen consumption*
	2. Carbon dioxide production*
	3. Pulmonary ventilation*
	Cardiovascular Function
	1. Resting pulse rate
	Central Nervous System
	1. Passage of Time
	2. Electroencephalogram
	Hematology
	1. Erythrocyte sedimentation rate*
	2. Total white cell count
	3. Differential white cell count
	Balances
	1. Calcium
	2. Urinary phosphorus*
	3. Urinary pH and titrable acidity
	4. Urinary ammonia nitrogen
	5. Intake of fat and carbohydrate
	Physical Fitness

*Data incomplete or considered to be technically unreliable. (See appropriate parts of Section III.)

TABLE IV. 5

RANK-ORDER OF REGIMENS: SUMMARY OF BIOCHEMICAL AND PHYSIOLOGICAL RATINGS

Experimental Regimen		Rank Hard Work	Light Work	Mean
N	U	1	2	1.5
3000	L	6	3	4.5
30/0/70	U	4	12	8.0
2000	L	14	15	14.5
15/52/33	U	2	1	1.5
2000	L	9	9	9.0
2/20/78	U	3	4	3.5
2000	L	5	13	9.0
0/100/0	U	8	5	6.5
2000	L	7	6	6.5
30/0/70	U	10	18	14.0
1000	L	18	19	18.5
15/52/33	U	10	7	8.5
1000	L	13	8	10.5
2/20/78	U	17	10	13.5
1000	L	16	14	15.0
0/100/0	U	15	11	13.0
1000	L	12	16	14.0
ST 0	U	20	17	18.5
	L	19	20	19.5

TABLE IV. 6

SUMMARY OF SYSTEM COMPLAINTS

Experimental Regimen	Incidence of System Complaints Water Unlimited	Water Limited	Total
N 3000	7	26	33
30/0/70 2000	25	37	62
15/52/33 2000	15	20	35
2/20/78 2000	21	30	51
0/100/0 2000	14	17	31
30/0/70 1000	40	32	72
15/52/33 1000	24	17	41
2/20/78 1000	33	29	62
0/100/0 1000	34	24	58
ST 0	36	49	85

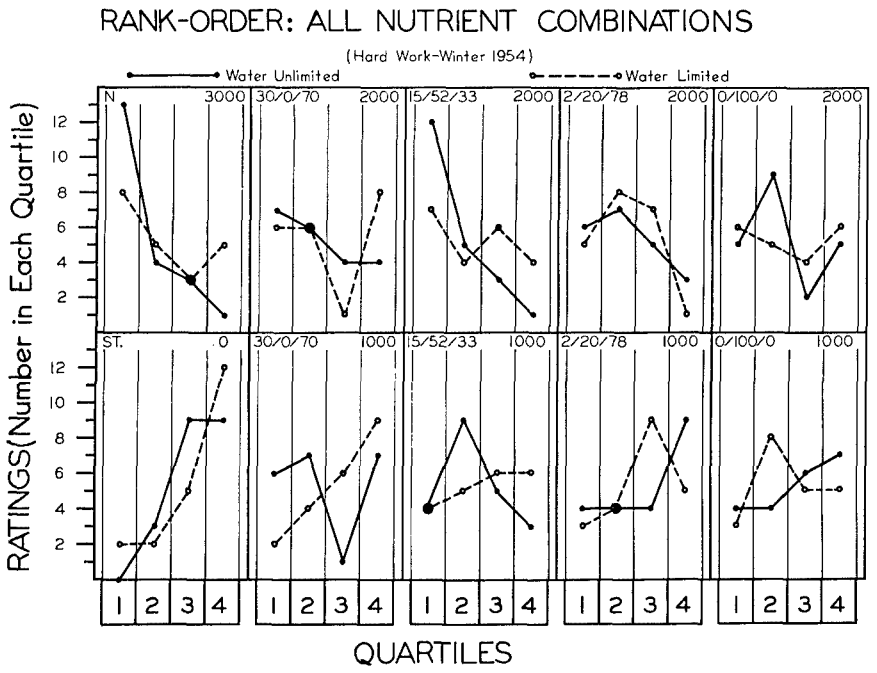

FIGURE IV. 1. RANK-ORDER: ALL NUTRIENT COMBINATIONS, HARD WORK, WINTER, 1954.

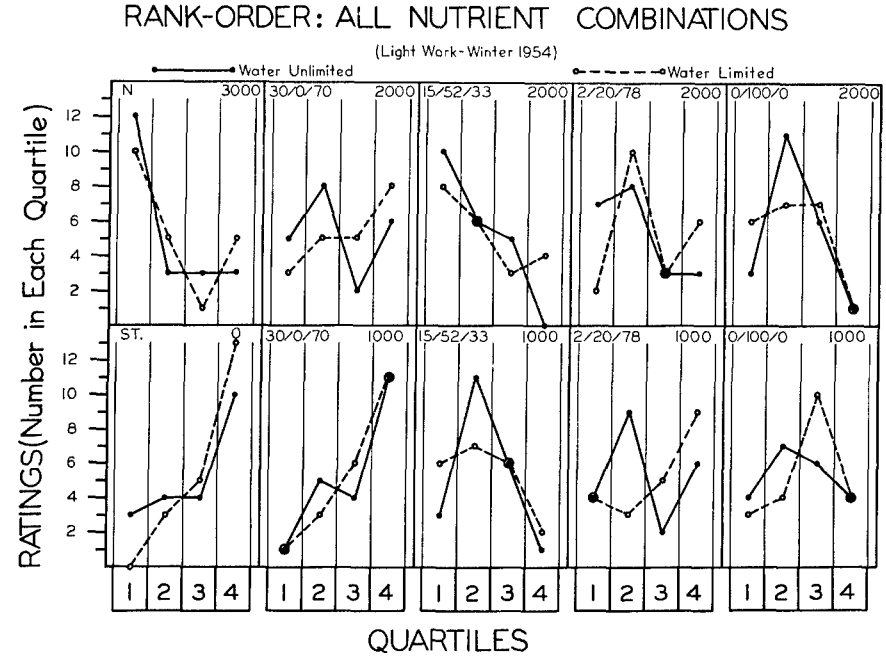

FIGURE IV. 2. RANK-ORDER: ALL NUTRIENT COMBINATIONS, LIGHT WORK, WINTER, 1954.

C. THEORETICAL IMPLICATIONS OF PRESENT STUDY

1. The Concept of the Balanced Diet

The nutritional literature (Lusk, 1928) uses the term "balanced diet" as a general concept of great importance in adequate diets. However, acceptable quantitative definition of this term is almost completely lacking. A typical example is: "A point of great interest is that of the proper proportion in which the individual food-stuffs should be put together in making up a ration...Voit defines a food as a well-tasting mixture of food-stuffs in proper quantity and in such proportion as will least burden the organism. What is the proper proportion?...It is also assumed that the food-stuffs are administered in a digestible form and therefore completely assimilable." (Lusk, 1928, p. 448). The history of modern nutrition is mainly the discovery of dietary essentials such as amino acids, vitamins, and trace elements. Ultimately cellular and enzymatic mechanisms will place the concept of a balanced diet on a sound basis but this event is far in the future. Meanwhile many standards for "optimal" nutrition have been proposed on the basis of evidence now at hand; the most influential of these are the U.S. National Research Council's Recommended Dietary Allowances (N.R.C., 1953). The holistic approach foreshadowed by Lusk and Voit is so costly and time-consuming that current recommendations are perforce based on a heterogeneous mass of isolated observations on animals and man.

Fortunately a unique series of circumstances has permitted the 1953 and 1954 studies on survival rations to investigate numerous organ functions of men on widely different regimens under such stresses that wide deviations from "normal" were produced. This body of data comprises one of the few systematic quantitative investigations which bear directly on the concept of the balanced diet. To be sure the time scale was short. Nevertheless, there are many independent sets of evidence which support for long periods of time the present generalizations.

Our generalizations on the balanced diet have been stated in Section III: There is a dietary ratio of protein, carbohydrate and fat which supports organismic efficiency even in undernutrition; when marked deviations from this ratio occur there are measurable disturbances in bodily efficiency or in the functioning of one or another organs or systems.

The detailed observations providing the bases of these generalizations have been given in Section III. of the present report and WADC TR 53-484, Part 1. The general categories in which minimal changes occurred with 15/52/33 and marked changes with 30/0/70, 2/20/78, or 0/100/0 were nutrient balances, body water, liver function, kidney function, gastrointestinal function, endocrine function, respiratory function, erythrocyte sedimentation and, perhaps most important of all, clinical signs and symptoms. These disturbances or their absence become evident in the rank ordering of nutrient combinations (Figure IV. 1, WADC TR 53-484, Part 1, and Figures IV. 1 and 2, present report).

Supporting evidence is to be found in the literature concerning self-selected diets if one grants the assumption that the individuals were healthy as claimed by the observers while subsisting on a free choice of foodstuffs. Outstanding among studies of self-selection of food in humans is that of Davis (1928). Her general conclusion was that infants will thrive when permitted to choose their own food after weaning for a period as long as 57 months. Pertinent to the present argument was the average distribution of calories by eight of her subjects. It was 17/47/36 (Table IV. 7), although deviations were considerable.

The nearest approach in military personnel to the work of Davis on infants was a study conducted by the Medical Nutrition Laboratory (1947) in which a group of 120 male soldiers (mean age, 19.3 years) subsisted for three weeks on items of C ration, each man choosing whatever he preferred for each meal. The 120 subjects averaged 4584 Cal/day in which the percentage distribution of protein, carbohydrate and fat was 12/61/27, respectively. During the same month 120 other soldiers were provided with an abundant fresh ration in which virtually free choice was permitted. Their caloric intake averaged 5067 with a percentage distribution of 14/42/44. Johnson and Kark (1947) collected all the data they could find in the military literature on the voluntary average nutrient intake of North American ground troops who remained healthy, fit, and efficient in different environments during World War II. The average caloric intake regardless of environment was 3760 and the percentage distribution of the calories was 12/51/37.

The accounts of explorers also contribute to this argument. After long experience in Arctic exploration, Peary (1910) selected a ration which took him to the North Pole and back. He and his men ate 4654 Cal/day of a ration the percentage distribution of which was 23/41/36 (Sargent et al. 1954). The most successful of all polar explorers, Amundsen (1913) used on his South Polar journey a ration providing 4290 Cal/day with a percentage distribution of 21/43/36. Consideration of evidence on self-selection is facilitated by Table IV. 8 which presents the groups, calorie consumption, percentage distribution of calories, and observer. One generalization is clear: Populations of wide differences in age and environment voluntarily chose diets providing roughly 10-25% of the calories in protein, 40-60% in carbohydrate, and 25-45% in fat; i.e., all groups chose diets approximating our balanced regimen.

What theoretical explanation can be offered for virtues of 15/52/33? All our evidence points in one direction. This regimen is associated with the least deviation of the internal environment under conditions of nutritional stress. That is, to say the homeostatic mechanisms of the whole organism are least disturbed. Richter (1942-43) makes the generalization that appetite for food, like thirst, is a homeostatic regulatory mechanism. What the body needs, the animal eats. We would conclude that the self-selected distribution of man allowed free choice of foodstuffs represents for him the balance required for optimal maintenance of the homeostatic processes.

TABLE IV. 7

DISTRIBUTION OF CALORIES AMONG PROTEIN, CARBOHYDRATE AND FAT IN SELF-SELECTED DIET OF EIGHT INFANTS*

Subject	Sex	Initial Age	Length of Study	Total Calories	P	CHO	F
		Mos.	Mos.	Cal/day	%	%	%
A.G.	M	8	57	1532	20	47	33
D.R.	M	10	50	1365	15	58	27
P.A.G.	F	9	42	1231	15	58	27
S.P.L.	F	6	42	1078	17	49	34
E.W.	F	10	36	1072	18	40	42
L.McC.	M	7	36	1184	18	42	40
P.C.	M	7	24	967	17	52	31
J.B.	M	11	24	1261	19	27	54
Mean	-	--	--	1211	17	47	36

*Based on original unpublished data kindly made available to authors by Dr. Clara M. Davis.

TABLE IV. 8

SUMMARY OF INFORMATION ON SELF-SELECTED DIETS IN MAN

Population and Environment	Caloric Intake	Distribution of Calories P	CHO	F	Reference
	Cal/day	%	%	%	
Infants, temperate	1211	17	47	36	Davis (unpublished data)
Soldiers, temperate	4584	12	61	27	Medical Nutrition Lab (1947)
Soldiers, temperate	5067	14	42	44	
Soldiers, temperate	3850	13	49	38	Johnson and Kark (1947)
Soldiers, Arctic	4400	11	49	40	
Soldiers, moist tropics	3350	12	55	33	
Explorers, Arctic	4654	23	41	36	Sargent et al. (1954)
Explorers, Antarctic	4290	21	43	36	

2. Minimum Nutritional Requirements

One important feature of life over protracted periods is that the healthy organism stays in nutrient balance. Body weight in most adults remains remarkably constant for months and years, and this phenomenon implies that balance with respect to all nutrients is achieved successfully.

Packaged rations are planned on the assumption that the ability of the individual to obtain extra food is limited, and one aim in packaged rations has always been to provide food adequate for nutrient balance in the average individual. A serious gap in nutritional knowledge has been precisely in lack of trustworthy quantitative data on minimal requirements of the average young man in different environments and with different work loads. The 1953 temperate

study, the present moderate cold study, and a 1948 study on survival in extreme cold (Medical Nutrition Laboratory, 1948) all collected data on nutritional balance after chemical analysis of intake, urinary excretion and fecal excretion, and their conclusions are directly comparable.

In arriving at figures for minimal requirements from these various studies, one important assumption must be made. It must be assumed that when several subjects were in, or approached, balance with respect to one or another nutrient, those with the least intake most closely represented the minimal requirement. On this basis, minimal requirements for balance have been calculated, and compared with U.S. National Research Council standards for young men (Table IV. 9).

For the most part, there is good agreement among the several studies on the order of magnitude for water, calories, sodium, chloride, carbohydrate, and fat. Such discrepancies as exist in these nutrients are explicable in terms of exposure to cold (extreme cold study) or hard work load with concomitant sweating (moderate cold, hard work). However, in the case of nitrogen and potassium, serious discrepancies exist. We are inclined to attribute these discrepancies to one or both of two factors. First, the digestibility of the protein sources for the extreme cold study was probably better than for the others, in all of which meat bar was used. We have reason to suspect that the digestibility of meat bar is lower than that for many other high protein sources such as milk powder. Second, a catabolic reaction was demonstrably present in the moderate cold groups. This manifested itself by an abnormally high excretion of nitrogen and potassium, with resultant indications of a large requirement for these two nutrients. This phenomenon will be discussed in detail below.

Although it may not be practical in survival rations to provide nutrients enough for the castaway, negative balances are deleterious to efficiency. The estimates we have been able to make are certainly goals which should be approximated as nearly as possible in survival rations, and which certainly should be reached when rations for adequate nutrition can be provided.

TABLE IV. 9

MINIMAL REQUIREMENTS FOR NUTRIENT BALANCE UNDER TEMPERATE CONDITIONS, MODERATE COLD, AND EXTREME COLD

Nutrient	Temperate	Moderate Cold		Extreme Cold,	NRC
	Light Work[1]	Hard Work[2]	Light Work[3]	Sedentary[4]	men, physically active[5]
Water, liters (including preformed and metabolic)	2.4	3.0	2.5	2.5	3.0
Calories, Cal	2700	3500	3000	3000	3200
Nitrogen, gm	15	20	16	8	11
Potassium, mEq	45	60	60	20	----
Sodium, mEq	100	140	75	100	86
Calcium, gm	0.6	----	----	1.1	0.8
Chloride, mEq	14	110	110	90	86
Phosphorus, gm	1.3	----	----	1.0	1.5
Carbohydrate, gm	340	440	375	400	495
Fat, gm	100	130	110	135	85
Vitamins	No clear evidence				

[1]Sargent et al., 1954
[2]Present report
[3]Present report
[4]Medical Nutrition Laboratory, 1948
[5]National Research Council, 1953

3. The Catabolic Reaction in the Castaway

In the clinical literature there is an important metabolic concept which is applicable to some aspects of survival. It is the "catabolic reaction" which is defined as reaction to injury characterized by a period of strong negative nutrient balance in the face of nutrient intakes which may be many times those considered normal. Convalescence involves an anabolic phase when nutrient balances become strongly positive. The interrelations between the endocrine glands and intermediary metabolism are certainly involved in this reaction, and Selye (1946) has incorporated the catabolic reaction into his General Adaptation Syndrome. Negative balances are characteristic of his phase of "shock" and positive balance of his "period of resistance". So far as nutrition is concerned, when the catabolic reaction is in progress, nutritional requirements will be greatly increased.

Evidence of the Catabolic Reaction in the Present Study. One of the most interesting features of the winter study was the presence of a mild catabolic reaction, presumably the resultant of all the stresses of the test, regardless of work load or dietary intake. This reaction continued throughout the two weeks and was followed by a very strong anabolic phase. Inasmuch as negative balances were to be expected in all experimental regimens except N-3000, we place considerable emphasis on the findings in the positive control groups. Regardless of intakes of calories and nutrients, these groups showed catabolic reactions in the following respects:

a) Calories
b) Water
c) Nitrogen
d) Potassium
e) Chloride
f) Phosphorus
g) Occasional ketonuria

The findings in these subjects exposed to moderate cold were in marked contrast to those for the temperate group of 1953. In that study the positive control period was characterized by lack of negative balances with respect to all nutrients except potassium. The moderate cold study of 1954 produced changes that were reminiscent of those noted in the extreme cold study of 1948 (Medical Nutrition Laboratory, 1948) in so far as nutrient balances are concerned.

Evidence of the Anabolic Reaction in the Present Study. During the recovery periods positive balances, sometimes of marked degree, were measurable in all subjects including those who had subsisted on the positive control regimen. These positive balances were present in the case of each nutrient studied. The striking feature of the anabolic reaction was the fact that --- even though the balances continued to be strongly positive --- there was very little change in the body weight. Most of the weight lost during the experimental periods had been restored by the end of REC I.

Implications of the Metabolic Reactions in Survival and Rehabilitation. Good evidence has now accrued from two cold weather field studies that a catabolic reaction occurs in the castaway exposed to cold weather followed by an anabolic phase after he is rescued. Theoretically speaking we agree with the hypotheses of the 1948 observers:

a) "...when well fed men are abruptly exposed to cold, the pituitary stimulates the adrenal cortex to increase all its functions;

b) "when the stress is continued, adaptation (or 'resistance') may be observed, with a continued increased function of the pituitary;

c) "when the men are inadequately fed in addition to being exposed to cold, the adaptation to cold will be incomplete; and when the stresses of cold and inadequate diets are removed, many 'rebound' phenomenon may be observed as rehabilitation takes place."

It is clear that the nutritional requirements of the castaway exposed to environmental stress are the resultant of two independent processes. First is the limitation of the food and water intake which may be imposed on him by

circumstances beyond his control. Second is the catabolic reaction to which situational stresses predispose him. Thinking on survival rations must take these complexities into account.

If to these nutritional and environmental stresses are added that of injury a catastrophic catabolic phase may ensue. Only heroic nutritional measures can overcome such a catabolic reaction even in a hospital.

Rehabilitation of the castaway also has its complexities. For its completion the anabolic phase requires almost unbelievable amounts of nutrients. If they are not provided, rehabilitation will not be complete.

Questions of extreme theoretical interest still remain. Why does the high positive energy balance not result in an equivalent gain in weight? Can it be due to the formation of high energy phosphate bonds, sulfur bonds, and other obligatory intermediates in the thermodynamics of the body? What are the clinical and biochemical criteria for the adequacy of rehabilitation? By what objective quantitative means may one judge that rehabilitation has been completed?

4. Interrelations among Osmotic Load, Body Water, and Renal Function

One of the most important generalizations ofour studies of 1953 and 1954 has been made possible by adequate quantitative means of measuring osmotic load, body water, and renal function. Mathematically these three are independent variables but in so far as nutrition is concerned they have turned out to be physiologically correlated variables in the sense that when one of the three changes the others do likewise.

From all of the data an equation has been derived which shows great promise of being of basic significance in measuring renal functional capacity in health and disease. It is

$$\frac{V_I}{V_o} = 5.00 \left(\frac{L-55.58}{L+17.67} \right)$$

where V_I is the isosmotic volume, V_o is the obligatory volume, and L is the osmotic load. One potential use might be in the measuring of the renal capacity of a patient suffering from disease of the kidney. After placing the patient on a constant diet one could vary his water consumption so as to measure V_I, V_o and L. The constant in this nephritic, similar to the 5.00 for normal, would then become directly a measure of renal concentrating ability. Since in renal disease, the specific gravity of the urine usually fixes at 1.010, one might predict that the constant would be less than 5.00.

In the specific problem of survival rations this equation can be expected to lead to important results in defining the osmotic and renal implications of any given regimen. Since renal and osmotic factors may become critical in the

sense of the weakest link in situations involving dehydration, a quantitative expression for any given regimen clearly is exceedingly desirable. "L" is the number which describes the total osmotic impact of a regimen, a quantity which cannot be calculated from known intakes of all nutrients, especially in undernutrition. For instance there is no known way to predict quantitatively the excretion of ketone bodies although these substances do play an important part in osmotic load. The expression "V_o" has been used by all previous research workers on the problem of water requirements in survival. To our knowledge no one has used the concept of the isosmotic volume (V_I) in this connection.

Our equation can be used for defining the osmotic characteristics of any given regimen. All that is required are measurements of urinary and serum osmotic pressure and urinary volume, all of which are very easy. If a normal subject is placed on a given regimen with water intake varied from day to day, it becomes possible to calculate the obligatory volume without ever dehydrating him.

V_I itself is an important factor in considerations of dehydration per se. For any given regimen the larger it is, the more likely is dehydration to become dangerous rapidly.

5. Limits of Homeostasis

A major concept in all physiology is that of homeostasis. The concept is implicit in the clinical terms "limits of normal" or "within the normal range". Statistically the concept of homeostasis has suffered in two major ways. First, a naive approach has been adopted by many who have talked of the constancy of the internal environment in a given individual as though it were fixed. Second, the past literature makes little or no reference in relation to homeostasis of measures of intra-individual variance or inter-individual variance. Without such an approach how can one answer the general questions: How constant is one's internal environment? What are the limits of normality between individuals? Our study of 1953 provided an unparalleled series of data on the first question and our study of 1954 on the second. Taking both studies into consideration an interesting series of generalizations can be made (Table IV. 10).

a) The concentration of inorganic substances in the serum is remarkably constant both within and between individuals. Methods for these substances are easy and highly reproducible.

b) Two groups may be discerned among the organic subjects. The first shows little if any more variability than the inorganic substances. It includes urea nitrogen, non-protein nitrogen, creatinine, glucose, and hematocrit. Methods for these substances are easy and well standardized. The second shows wide intra- and inter-individual variability. It includes amylase, cholinesterase, lipase, alkaline phosphatase, cholesterol, and erythrocyte sedimentation rate. Measurement of these is technically somewhat unsatisfactory.

c) In seeking for a rational classification of these variabilities, one notes that the least intra- and inter-individual variation is found among the

inorganic ions and those molecules which represent a substrate or an end-product of metabolism; the greatest variability among enzymes and inter-mediates and measurements related to intermediary metabolism.

d) With but one exception, serum cholinesterase, there is very close agreement between inter- and intra-individual variance.

For most substances the limit of homeostasis appears to be a coefficient of variation of 15%. For other substances, notably enzymes, the human body permits very wide fluctuations. Why are some substances given such precise regulation while others are permitted to vary? The present approach offers a fruitful line for future research on such a question. Studies with this naturalistic point of view are notably lacking, but they would contribute greatly to increasing our knowledge of human biology.

TABLE IV. 10

LIMITS OF HOMEOSTASIS

Determination	Coefficient of Variation	
	Intra-Individual*	Inter-Individual** Within Groups
Serum		
Osmolarity	---	2.7 - 5.3
Sodium	2.0 - 2.8	1.4 - 2.9
Potassium	3.6 - 11.8	2.4 - 11.9
Calcium	1.9 - 7.7	6.4 - 11.1
Inorganic Phosphate	1.3 - 11.8	8.0 - 14.6
Chloride	1.6 - 3.5	1.0 - 2.9
Amylase	8 - 34	20 - 55
Cholinesterase	2.2 - 11.8	14.6 - 26.9
Lipase	31 - 71	---
Alkaline Phosphatase	---	22.8 - 47.7
Non-Protein Nitrogen	---	6.7 - 10.7
Urea N	4.5 - 18.4	---
Creatinine	2.0 - 18.2	8.7 - 18.5
Glucose	6.2 - 12.1	4.9 - 14.2
Cholesterol	6 - 28	14.4 - 33.3
Whole Blood		
Sedimentation Rate	20 - 100	46 - 80
Hematocrit	2.4 - 6.3	4.2 - 6.7

*Based on data collected on eight subjects measured six times in 1953.
**Based on data collected on five groups measured twice in 1954: The groups contained 22, 22, 22, 21 and 12 subjects, respectively.

D. IMPORTANT UNSOLVED PRACTICAL PROBLEMS

The present report has dealt with survival rations for men in moderate cold engaging in work simulating escape and evasion or light work such as a castaway might be performing while awaiting rescue. The previous report (Sargent et al., 1954) dealt with survival regimens as used under temperate conditions by men engaged in moderate activity. The conclusions of both studies are the same. The same balanced regimen with ample water is least deleterious under all three conditions. A similar conclusion was reached by previous workers (Medical Nutrition Laboratory, 1948) on studies of sedentary men exposed to extreme cold. We take it therefore as demonstrated that the same survival ration can and should be used for temperate, moderate cold, and extreme cold conditions.

One major environment condition still remains to be studied: hot weather. If an all-purpose survival ration is ultimately to be adopted, it is essential that the generalizations of the present report be examined in the light of painstaking, systematic, statistically adequate, comprehensive clinical studies in the field on healthy subjects under conditions of hot weather and the stresses of physical exercise in simulated survival situations. The subjects should subsist on nutrient combinations similar to those used in the 1953 and 1954 investigations.

Plans are in progress at the present time to conduct such a field study at Camp Atterbury, Indiana, during the months of June, July, and August, 1955. The subjects will be handled in much the same manner as that described in this report. The measurements to be made will include all those which have proved to be discriminatory in previous studies with the addition of specific measurements on sweat and thermal balance. The results of such a study should make possible an answer to the question: Can there be a single all-purpose all-weather survival ration?

One important aspect of survival should not be forgotten. The castaway may be suffering from physical injury. What then are his nutritional requirements? Certainly they are not those of an uninjured man. This aspect of survival needs systematic studies on patients hospitalized because of traumatic injury.

SECTION V

SUMMARY

A. Purposes of Study.

1. From February 22, 1954 through April 4, 1954, 87 volunteer airmen and 12 volunteer non-commissioned officers served in a field investigation which contributed basic knowledge to the general problem of the all-purpose, all-environment survival ration.

2. The general aims of the study were four:

a. To study comprehensively from the standpoint of total efficiency and the functioning of important organs and organ systems, the reactions of healthy young men to a variety of restricted nutritional regimens under conditions of moderate cold in a field survival situation.

b. To simulate the two major kinds of survival; viz., escape and evasion (hard work, 12 miles of marching daily) and waiting for rescue (light work, 3 miles of marching daily).

c. To correlate these results with a previous study on subjects under temperate conditions performing moderate work.

d. To study the nutritional problems of recovery after a period of restriction.

B. Methods of Study.

1. To establish physiological, biochemical, nutritional, and clinical judgments on the relative effects of water intake, caloric intake and the ratio of protein, carbohydrate, and fat in the survival ration, numerous observations were made in three two-week periods of adequate, restricted and recovery diets, with luxus amounts of vitamins at all times.

2. In the design of the experiments, four kinds of statistical controls were employed:

a. Starvation and a 3000-Calorie adequate ration represented the worst and best regimens. These were designated as "negative control" and "positive control", respectively.

b. Each subject was considered his own control with respect to changes in pre-periods, experimental periods and recovery periods.

c. Paired controls were planned for every experimental period, in that for each nutrient combination one subject received unlimited amounts of water and another was restricted to 910 ml of fluids per day.

d. Ration controls, the twelve non-commissioned officers who lived and worked with their men, subsisted on A Ration at all times.

3. Twenty nutrient combinations included the variables:

a. Calories - 0, 1000, 2000 and 3000 per day.

b. Water - unrestricted and limited to 910 ml of fluid per day.

c. Approximate distribution of calories - 0, 3, 13 and 30% from protein; 0, 18, 55 and 100% from carbohydrate; and 0, 32, 70 and 79% from fat.

4. The actual diets that were used were prepared from components of USAF rations and commercial foods.

a. Pre-periods: 5-in-1 ration.

b. Experimental periods:

(1) 30/0/70: meat bar; high protein, high fat.

(2) 15/52/33: meat bar from the Ration, Special Survival, bread unit (5-in-1), catsup, jam (5-in-1), and raisins; "normal mixture"; protein, carbohydrate, and fat in average proportions.

(3) 2/20/78: oleomargarine and saltine crackers; high fat.

(4) 0/100/0: candy components of the ST Ration; pure carbohydrate.

(5) N-3000: positive control; 3000 Cal/day of 15/52/33.

(6) ST 0: starvation; no food.

c. Recovery periods: week 1, three days of gradually increased intake followed by four days of 5-in-1 ad libitum; week 2, A Ration ad libitum.

5. In the actual scheduling all subjects were at Chanute AFB subsisting on the pre-period diet with unlimited water. In the experimental period, all subjects simulated survival in the field at Camp McCoy, Wisconsin and were separated into four flights:

Flight 1: hard work, water unlimited
Flight 2: hard work, water limited
Flight 3: light work, water unlimited
Flight 4: light work, water limited

In recovery all subjects were again at Chanute AFB with unlimited water.

6. During the entire six weeks the subjects were under close medical supervision. Continuous quantitative collections were made of urine and feces; and complete dietary records were kept of food and fluid consumption. At regular intervals specimens of venous blood were drawn for analysis, and the subjects were subjected periodically to special biochemical, physiological, and clinical tests.

7. All methodology was validated statistically. For the most part standard accepted methods were used, but in some areas new methods had to be devised.

C. Results of Study.

1. In general, the biochemical and physiological results could be classified according to their pertinence in elucidating the problem of survival rations. Criteria of pertinence included the concepts that the measurement should be predictive of potential deterioration, should discriminate among nutrient combinations tested, and should be interpretable in terms of current clinical thought.

2. Twenty-one radically different kinds of measurements proved to be valid for rank-ordering the 20 different nutrient combinations in terms of their protection against possible deterioration with respect to efficiency of the body as a whole and the functioning of organs. The 21 may be categorized as follows:

a. Nutrient balances - calorie; water; nitrogen; sodium; potassium; chloride; acid-base (as measured by urinary excretion of acetone bodies).

b. Body composition - change in body weight; change in body water; water diuresis test.

c. Liver function - serum cholinesterase.

d. Kidney function - creatinine clearance; mean volume of daily urine; osmolar clearance as related to the urine/serum osmolar ratio; formed elements in the urine (red blood cells and casts); serum non-protein nitrogen.

e. Endocrine function - urinary excretion of neutral 17-keto-steroids and serum chloride (adrenal cortex); blood sugar (pancreas).

f. Gastrointestinal function - serum amylase.

3. Many other measurements were made, but not used, in arriving at the final judgments on the relative merits of the 20 nutrient combinations. Either the measurements showed no difference among nutrient combinations, or they were autocorrelated with other discriminatory measurements, or they did show differences which are not interpretable at present in terms of "survival potential". They may be categorized as follows:

a. Nutrient balances - calcium; urinary pH, titrable acidity, and ammonia; urinary phosphorus; intake of fat and carbohydrate.

b. Body composition - body fat.

c. Liver function - serum cholesterol.

d. Kidney function - minute urinary volume; albuminuria; white blood cells and epithelial cells in urine; serum osmolarity; urinary osmotic excretion; osmolar clearance; serum creatinine; minute urinary creatinine.

e. Gastrointestinal function - characteristics of feces; fecal fat and fat absorption; qualitative examination of feces.

f. Respiratory function - pulmonary ventilation; respiratory quotient; oxygen consumption; and carbon dioxide production.

g. Cardiovascular function - pulse rate; blood pressure; electrocardiogram.

h. Nervous system - time; psychological tests; electroencephalogram.

i. Endocrine function - serum calcium, phosphorus, and alkaline phosphatase; urinary creatine; serum sodium and potassium.

j. Hematology - hematocrit; total white cell count; differential leukocyte count; erythrocyte sedimentation rate.

4. Daily clinical records were kept and periodic complete physical examinations were made by four medical officers. In the final judgment concerning the relative merits of the 20 nutrient combinations, clinical considerations were given substantial weight, for it is well known that clinically detectable deterioration may precede abnormal changes in physiological, biochemical, or nutritional measurements, and that the clinical severity of a syndrome may not be correlated with the degree of abnormality of those measurements.

a. Of the 87 volunteer airmen only five were unable to complete the two-weeks of restricted regimen in the field. Their cases were:

Mumps, one case on starvation
Exhaustion, three cases all on starvation
Fat intolerance, one case on 2/20/78 2000.

b. Consistent symptoms occurred in relation to some of the nutrient combinations, and these symptoms were aggravated by water deprivation at 2000 and 3000 Cal/day. The symptoms were chiefly referable to the gastrointestinal tract and the nervous system, and were present during subsistence on regimens the composition of which deviated widely from the normal mixture.

D. Specific Conclusions from Study.

1. Hard Work.

a. With unlimited water, no nutrient combination ranked as high as the positive control at 3000 Cal/day or as low as starvation.

b. With limited water only two combinations, 0/100/0 2000 and 2/20/78 2000 ranked close to the positive control with 15/52/33 not far behind; and none was as bad as starvation.

c. Regardless of water intake, no nutrient combination at 1000 Cal/day ranked as high as the same nutrient combination at 2000 Cal/day.

d. Water restriction worsened the score of every nutrient combination except the lowest osmotic regimens --- 0/100/0 1000, 0/100/0 2000, and 2/20/78 1000.

2. Light Work.

a. With unlimited water one regimen, 15/52/33 2000, was close to the positive control and one regimen, 30/0/70 1000, was as bad as starvation.

b. When water intake was limited, no regimen was as good as the positive control or as bad as starvation.

c. Regardless of water intake nutrient regimens at 2000 Cal/day scored better than they did at 1000 Cal/day except 15/52/33.

d. With no exceptions limitation of water worsened the score of every nutrient combination.

E. General Conclusions from Study.

1. In the present study conclusions for hard work and light work were the same. Furthermore they agree with conclusions for temperate conditions as studied previously.

2. Although every nutrient combination possessed definite defects, when judged finally upon biochemical, physiological, and nutritional grounds, as well as clinical, the combination that stood next to the adequate 3000 Calorie control ration was the "normal mixture" at 2000 Calories without restriction of water. Of the 1000 Calorie combinations, the least deleterious was also the "normal mixture".

3. On the basis of past military and civilian experience, and the present studies, it must be concluded that the survival potential of a castaway exposed either to temperate or cold conditions and regardless of work load is best maintained by a liberal intake of water and calories, and a ration that provides in acceptable form a distribution of calories approximating 15% from protein, 52% from carbohydrate and 33% from fat.

In addition, all known vitamins should be provided in luxus amounts.

F. Theoretical Implications of Present Study.

1. There is a distribution of calories (approximately 15/52/33) among protein, carbohydrate and fat which best supports body efficiency even in undernutrition. Marked deviations from this distribution cause disturbances which can be detected clinically or functionally.

2. Minimal requirements for nutritional balance have been estimated from studies on subjects in extreme cold, moderate cold, and temperate conditions with respect to water, calories, protein, fat, carbohydrate, sodium, potassium, calcium, chloride, and phosphorus.

3. A castaway exposed to cold displays a catabolic reaction characterized by negative nitrogen and potassium balances out of proportion to the intakes. In rehabilitation this catabolic reaction is replaced by an anabolic reaction with marked positive balances.

4. An equation relating isosmotic urine volume, obligatory urine volume, and osmotic load has been derived. This equation is useful in a variety of ways for studying the interrelations among osmotic load, body water, and renal function.

5. Study of the coefficients of variation of numerous constituents of the blood in men measured repeatedly under standard conditions leads to the concept that the normal limits of homeostasis are ± 15%.

G. Important Unsolved Practical Problems.

1. Important unsolved problems remain which can be solved only by comprehensive field and hospital studies with emphasis on the efficiency of the body as a whole and the functioning of organs and organ systems. Foremost among these are:

a. What is the effect of extreme heat on the castaway's nutriture?
b. What are the nutritional requirements of an injured castaway?

SECTION VI

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SECTION VII

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1. Administrative Personnel

Lt. Col. Roy W. Otto, AO284452, Project Officer (1)
WOJG Gerald J. Ramagos, AW2201876, Adjutant (1)
M/Sgt Raymond H. Poland, AF6802540, First Sergeant (1)
A/1C Eddie R. Devers, AF18297139, Clerk (1)

Survival Instructors

Mr. Norman Bright (2)
Mr. James Kramer, also meteorological observer (2)
Mr. Raymond Fuller (2)
A/2C Anthony V. Gauba, AF19421184 (1)

Supply

Mr. Raymond Fuller, Responsible Supply Officer (2)
Mr. Louis W. Huart, Asst. Responsible Supply Officer (2)
S/Sgt Harold E. Goss, AF15246233, Supply Sergeant (1)

Transportation

S/Sgt William E. Rose, AF12010054, Motor Sergeant (1)
A/1C Phillip L. Burgess, AF11222566, Maily Orderly (1)
A/1C Dale L. Hanen, AF17316209, Truck Driver (1)
A/1C Clyde Kalas, AF27931048, Truck Driver (1)
A/1C David T. Laberee, AF17291327, Truck Driver (1)
A/2C Waldemar W. Holzhausen, AF16395598, Truck Driver (1)

Mess

S/Sgt Frank McArdle, AF36730747, Mess Sergeant (1)
A/1C James A. Brodie, AF14428878, Cook (1)
A/1C Allen A. Hilgendorf, AF16383487, Cook (1)
A/1C Everett L. Ricketts, AF16444631, Cook (1)
A/2C Gene E. Librock, AF12406654, Cook (1)

General Duty

S/Sgt Walter C. Brungard, AF13343109 (1)
S/Sgt James E. Saunders, AF14503272h (1)
A/1C Charles E. Gadsey, AF14370576 (1)
A/1C James Hibbs, AF13422836 (1)
A/1C Francis J. Mangold, AF16387845 (1)
A/1C Burl E. Farmer, AF15482233 (1)
A/2C Charles E. Poupard, AF16380890 (1)
A/3C Richard W. Pickenpaugh, AF17392464 (1)
A/B John T. Coleman, AF14493646 (1)

Flight Leaders

T/Sgt George J. Bacherd AF1401208, Leader of Flight 2 (1)
T/Sgt Charles J. Leatherman, AF13161093, Leader of Flight 4 (1)
T/Sgt Robert L. Taber, AF35965388, Leader of Flight 1 (1)
T/Sgt Logan P. Terrell, AF15213078, Leader of Flight 3 (1)
S/Sgt Cornelius F. Cain, AF16285232, Asst. Leader (1)
S/Sgt Kenneth W. Dangle, AF13367065, Asst. Leader (1)
S/Sgt John W. Dickey, AF19349088, Asst. Leader (1)
S/Sgt Donald C. Oliver, AF14379344, Asst. Leader (1)
A/1C John C. Durham, AF19390885, Asst. Leader (1)
A/1C Roger F. Kennedy, AF13388865, Asst. Leader (1)
A/1C Eugene P. Kraszewski, AF15460710, Asst. Leader (1)
A/1C Clarence A. Wilson, AF15438499, Asst. Leader (1)

Volunteer Subjects

Abercrombie, Joseph	A/3C	AF15512767
Allen, Bobby J.	A/3C	AF14512345
Anderson, Fred	A/3C	AF18451304
Anderson, Samuel	A/3C	AF14506177
Armstrong, Frederick	A/3C	AF13476863
Armstrong, John H.	A/3C	AF13476862
Beavers, Thomas L.	A/3C	AF14508546
Blackmon, Nathaniel	A/3C	AF14522112
Brown, Bobby J.	A/3C	AF25295474
Brown, Robert L.	A/3C	AF17382583
Byrd, Stephen	A/3C	AF16449669
Cope, Thurman D.	A/3C	AF18448962
Daniel, Mizell	A/3C	AF14522115
Daniels, Eugene W.	A/3C	AF26391724
Delgado, Erineo G.	A/3C	AF18446287
Downard, Jack A.	A/3C	AF24631014
Eaton, Delbert D.	A/3C	AF18452270
Echols, John T.	A/3C	AF14508554
Edwards, Cleon	A/3C	AF16456659
Edwards, Lester	A/3C	AF19490505
Edwards, William E.	A/3C	AF16456590
Embery, Hilbert D.	A/3C	AF16456616

Evans, Virgil L.	A/3C	AF17382615
Ferrell, Richard L.	A/3C	AF18451306
Ficklin, Lanier	A/3C	AF19490492
First, Robert J.	A/3C	AF16456636
Fitzgerald, Donald	A/3C	AF14508536
Ford, Robert	A/3C	AF16456647
Ford, William H.	A/3C	AF16453257
Fuller, Waldron A., Jr.	A/3C	AF14501422
Gildersleeve, George E.	A/3C	AF16456629
Goff, James W.	A/3C	AF16453258
Greene, Raymond M.	A/3C	AF13476857
Gulley, Al, Jr.	A/3C	AF17390377
Gulley, Harold R.	A/3C	AF16456650
Harris, Major	A/3C	AF18438448
Hernandez, Daniel, Jr.	A/3C	AF18443988
Hill, Johnny E.	A/3C	AF14506094
Hollifield, Tommy T.	A/3C	AF16449657
Hood, Clarence	A/3C	AF18445904
Johnson, Carl F.	A/3C	AF15510579
Johnson, Willie	A/3C	AF18448968
Jones, Bobby J.	A/3C	AF14518058
Jones, R. V.	A/3C	AF18450476
Lauary, Johnnie, Jr.	A/3C	AF17382571
Lee, Norman L.	A/3C	AF16453229
Mack, Julius	A/3C	AF14506191
McDevitt, Charles J.	A/3C	AF14499544
Meador, Leon B.	A/3C	AF14513087
Miller, James D.	A/3C	AF14510391
Mix, O. L.	A/3C	AF14508537
Momon, James F.	A/3C	AF16456628
Mullins, Charles E.	A/3C	AF15510570
Murphy, Carl D.	A/3C	AF15515630
Normand, Rudy F.	A/3C	AF18451303
Norrington, S. M.	A/3C	AF14508314
Nuqui, Eduardo	A/3C	AF19490478
Patterson, Bobby C.	A/3C	AF17382649
Paul, Rudolph O.	A/3C	AF16449666
Payton, William A.	A/3C	AF14512346
Pope, Eugene	A/3C	AF14522104
Porter, Otis L.	A/3C	AF16456563
Rance, Arthur L.	A/3C	AF16456582
Reed, Floyd K.	A/3C	AF15510571
Reed, Ralph E.	A/3C	AF17382618
Ross, Joseph H.	A/3C	AF13476860
Ruedy, Roger O.	A/3C	AF17394755
Rutledge, Carl E.	A/3C	AF16453261
Sada, Gerardo A.	A/3C	AF18450467
Saldana, Jesus	A/3C	AF18443896
Sanders, James C.	A/3C	AF16449662
Schraeder, Kenneth C.	A/3C	AF16449653
Singleton, Charley L.	A/3C	AF18451303

Smith, Donald	A/3C	AF17382570
Stanton, Delrimple	A/3C	AF16449653
Stevenson, Carl A.	A/3C	AF17382588
Surratt, Thamous	A/3C	AF18448967
Tallent, Howard L.	A/3C	AF14501613
Thada, Roy C.	A/3C	AF16454533
Thomas, Frank	A/3C	AF14499546
Upton, Henry I.	A/3C	AF14506190
Vaughn, James A.	A/3C	AF16449664
Wade, John G.	A/3C	AF14517071
Walker, Clarence W.	A/3C	AF13476703
Ward, Joe L.	A/3C	AF19490493
Wilson, William B.	A/3C	AF18452282
Witzke, Robert L.	A/3C	AF19498199

2. Technical Personnel (Field Phase)

Capt Frederick Sargent, II, AO2240272, Supervisory Investigator (2)

Medical Group

Capt William I. Mandel, AO1939175, Medical Officer (1)
Capt Gerard B. Schroering, Jr., 22971A, Medical Officer (3)
Capt Jack E. Steele, AO2213958, Medical Officer (2)
1/Lt Augusto Ortiz, AO2260079, Medical Officer (4)
M/Sgt John R. Bilich, AF12162495, Medical NCO (1)
S/Sgt Dwight C. Kelsey, AF11205982, Medical NCO (1)
A/1C Earl W. Jackson, AF16391582, Medical NCO (1)
A/2C Robert L. Lightner, AF13414302, Medical NCO (1)

Dietetics Group

Mrs. Virginia W. Sargent, Chief Research Dietitian (5)
Mrs. Joan Williams, Asst. Research Dietitian (5)
Mess Personnel (listed above)

Clinical Laboratory

Dr. Raymond F. Kline, Task Scientist (2)
Dr. William A. Boyd, Research Assistant (5)
Dr. Andrew A. Pandazi, Research Assistant (5)
Miss Margaret M. Jackson, Laboratory Technician (2)
Miss Dorothy L. Leffel, Laboratory Technician (2)
Mrs. Enid J. Meltzer, Laboratory Technician (5)
1/Lt Robert B. Hayling, AO2220589, Laboratory Technician (2)
Mr. Clifford D. Howell, Photographer (2)
A/2C Silvio S. Alaimo, AF12368118, Laboratory Asst. (1)
A/2C Milo W. Bowman, AF15406638, Laboratory Asst. (1)
A/2C Mack Jackson, AF17359075, Laboratory Asst. (1)

3. Technical Personnel (University of Illinois)

Dr. Robert E. Johnson, Responsible Investigator
Capt Frederick Sargent, II, A02240272, Supervisory Investigator
Dr. Stanley G. Stolpe, Asst. Responsible Investigator

Chemical Analyses

Dr. William A. Boyd, Research Assistant
Dr. Ira Lichton, Research Assistant
Dr. Andrew A. Pandazi, Research Assistant
Mr. Robley D. Evans, II, Research Assistant
Mr. Alfred S. C. Ling, Research Assistant
Mr. Sabath F. Marotta, Research Assistant
Mr. Sherwin S. Mizell, Research Assistant
Mr. Thomas W. Nielsen, Research Assistant
Mrs. Jean Sonder, Research Assistant
Mr. James Watts, Research Assistant
Mrs. Enid J. Meltzer, Laboratory Technician
Mrs. Dorothy Milich, Laboratory Technician
Mrs. Virginia Stolpe, Laboratory Technician
Mrs. Lorna B. West, Laboratory Technician
Miss Alice Conn, Laboratory Assistant
Miss Yukiko Nakano, Laboratory Assistant
Mrs. Stella Montgomery, Jr. Laboratory Assistant

Dietary Analyses

Mrs. Virginia W. Sargent, Chief Research Dietitian
Mrs. Joan Williams, Research Dietitian
Mrs. Norma Austin, Dietetics Assistant
Miss Chloe Jordan, Dietetics Assistant
Miss Martha Prather, Dietetics Assistant

Draftsman

Mr. Jamal Samiany

Typist

Mrs. Norma Templin

In addition to those individuals who actively participated in the investigation there are others who did not but whose assistance, advice, and encouragement contributed substantially to the success of the venture. Their help can not be adequately expressed in words. We therefore will merely list them according to the organizations which employed them.

4. University of Illinois

Business Office

Mr. Lawrence E. Bailey, Supervisor, General Chemistry Stores
Mr. Lester E. Elliott, Senior Purchasing Assistant
Mr. James E. Osborn, Assistant Director of Purchases

Department of Physiology

Mr. F. B. Dilley, Jr., Instrument and Measurement Technician
Mr. Russell J. Gillogly, Jr., Laboratory Assistant
Mrs. Mary F. Leep, Typist
Mr. Olen Mackey, Jr., Laboratory Assistant
Mrs. Myra L. Semones, Typist

Department of Horticulture

Dr. Dwight Powell, Professor of Plant Pathology
Mr. Cornelius J. Rund, Chief Cold Storage Operator

5. Chanute Air Force Base

Major General Byron E. Gates, Commander, Chanute Air Force Base, Illinois
Colonel Roland B. Charron, Wing Executive
Colonel John Ficicchy, Jr., Base Surgeon
Colonel Grover L. Wilson, Commander, 3345th Technical Training Group
Lt Colonel Emmett E. Cockrum, Group Operations Officer
Major William F. Newton, Transportation Officer
Major Stephen A. Levandoski, Jr., Base Operations Officer
Captain John W. Nordstrom, Motor Pool Officer
Mr. Garneth E. Waespe, Training Analysis and Development Officer
Mr. Everett C. Iverson, Principal Instructor, Department of Crafts and Trades Training
Mr. Vernon C. L. Martin, Senior Instructor, Survival Training Course

6. Reynolds Aluminum Co.

Mr. Richard Holder, Field Representative

7. Camp McCoy (5th Army)

Lt Colonel George P. Long, Post Commander

FIGURE VII. 1. ADMINISTRATIVE PERSONNEL, LEFT TO RIGHT FRONT ROW: L. W. HUART, CAPT F. SARGENT, II, LT COL ROY W. OTTO, WOJG G. J. RAMAGOS, J. KRAMER, AND S/SGT W. C. BRUNGARD. BACK ROW: S/SGT J. E. SAUNDERS, S/SGT H. E. GOSS, M/SGT R. H. POLAND, A/1C E. R. DEVERS, AND A/1C P. L. BURGESS.

FIGURE VII. 2. FLIGHT LEADERS: LEFT TO RIGHT FRONT ROW: S/SGT J. W. DICKEY, T/SGT G. J. BACHERD, S/SGT K. W. DANGLE, A/1C J. C. DURHAM, A/1C C. A. WILSON, AND T/SGT L. P. TERRELL. BACK ROW: T/SGT R. L. TABER, A/1C R. F. KENNEDY, T/SGT C. J. LEATHERMAN, S/SGT C. F. CAIN, A/1C E. P. KRASZEWSKI, AND S/SGT D. C. OLIVER.

FIGURE VII. 1

FIGURE VII. 2

FIGURE VII. 3. PERSONNEL OF FLIGHT 1

FIGURE VII. 4. PERSONNEL OF FLIGHT 2

FIG. VII. 5

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FIGURE VII. 5. PERSONNEL OF FLIGHT 3

FIG. VII. 6

FIGURE VII. 6. PERSONNEL OF FLIGHT 4

FIGURE VII. 7. TECHNICAL PERSONNEL (FIELD). LEFT TO RIGHT FRONT ROW: DR. R. F. KLINE, MISS M. M. JACKSON, MRS. E. J. MELTZER, MISS D. L. LEFFEL, AND A/2C S. S. ALAIMO. BACK ROW: A/2C M. W. BOWMAN, 1/LT R. B. HAYLING, DR. A. A. PANDAZI, A/2C M. JACKSON, AND DR. W. A. BOYD.

FIGURE VII. 8. TECHNICAL PERSONNEL (UNIVERSITY). LEFT TO RIGHT FIRST ROW: MRS. J. K. SONDER, MRS. V. STOLPE, MRS. S. MONTGOMERY, MISS A. CONN, MRS. D. MILICH, MRS. L. B. WEST, AND DR. R. E. JOHNSON. SECOND ROW: DR. S. G. STOLPE, A. S. C. LING, J. WATTS, J. SAMIANY, AND DR. I. LICHTON. THIRD ROW: R. J. GILLOGLY, T. W. NIELSEN, S. S. MIZELL, R. D. EVANS, AND O. MACKEY.

FIG. VII. 7

FIGURE VII. 7

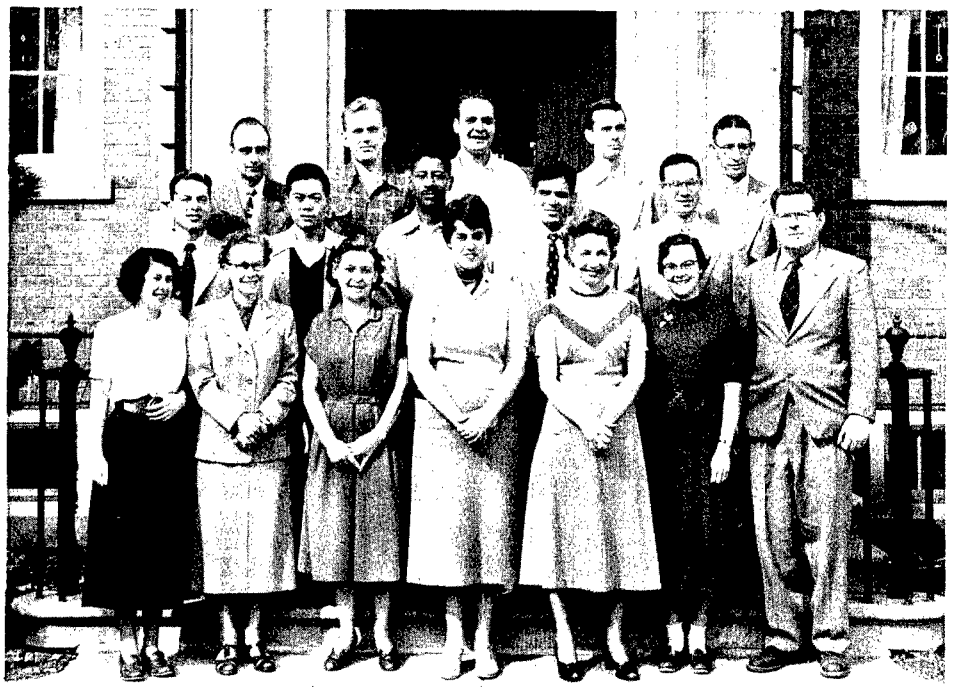

FIG. VII. 8

FIGURE VII. 8

FIGURE VII. 9. MESS PERSONNEL. LEFT TO RIGHT: A/1C J. A. BRODIE, S/SGT F. McARDLE, A/1C E. L. RICKETTS, AND A/1C A. A. HILGENDORF.

FIGURE VII. 10. TRANSPORTATION PERSONNEL. LEFT TO RIGHT: S/SGT W. E. ROSE, A/1C C. KALAS, A/1C D. T. LABEREE, AND A/2C W. W. HOLZHAUSEN.

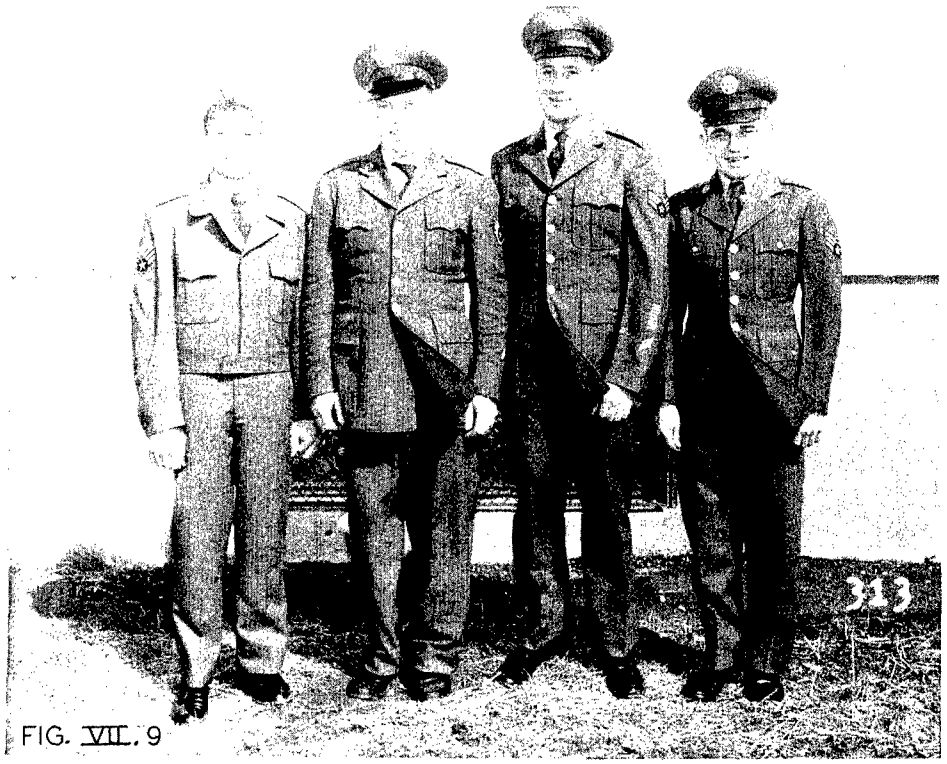

FIGURE VII. 9

FIGURE VII. 10

FIGURE VII. 11. MEDICAL OFFICERS. LEFT TO RIGHT: CAPT W. I. MANDEL, CAPT G. B. SCHROERING, CAPT J. E. STEELE, CAPT F. SARGENT, II, AND 1/LT A. ORTIZ.

FIGURE VII. 12. NON-COMMISSIONED MEDICAL OFFICERS. LEFT TO RIGHT: A/1C E. W. JACKSON, S/SGT D. C. KELSEY, M/SGT J. R. BILICH, AND A/2C R. L. LIGHTNER.

FIGURE VII. 11

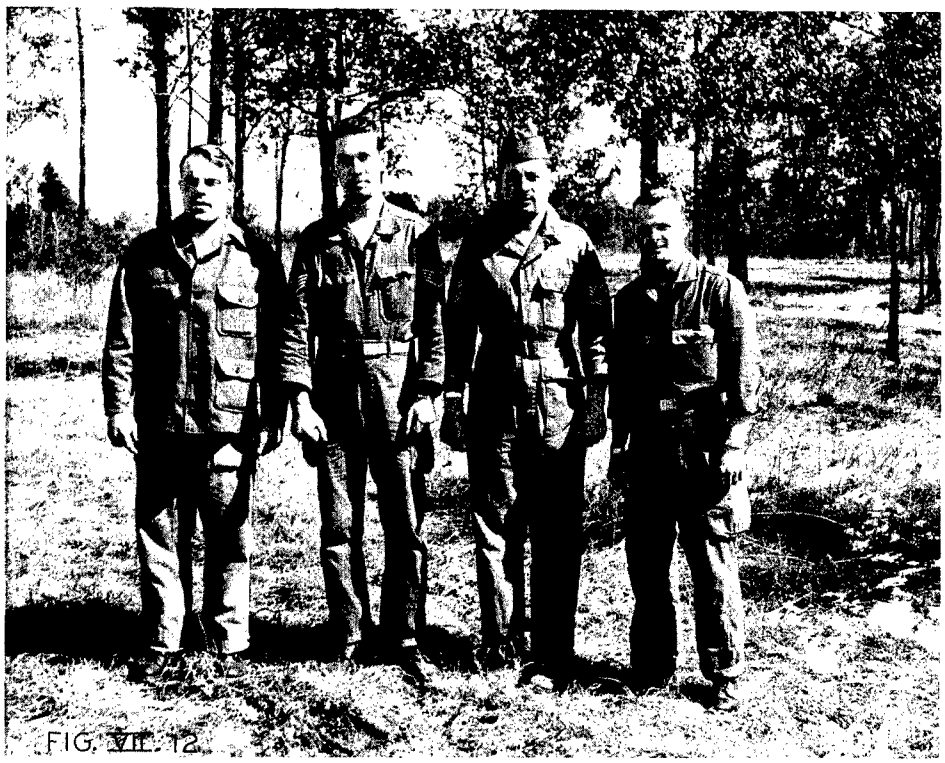

FIGURE VII. 12

FIGURE VII. 13. GENERAL DUTY PERSONNEL LEFT TO RIGHT: A/1C J. HIBBS, A/1C C. E. GADSEY, S/SGT W. C. BRUNGARD, A/1C F. J. MANGOLD, AND A/B J. T. COLEMAN.